Simulator Platform Motion Requirements for Recurrent Airline Pilot Training and Evaluation

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ACRONYMS AND ABBREVIATIONS

AC	Advisory Circular
a_{cg}	Acceleration at center of gravity
AGL	Above Ground Level
ANOVA	Analyses of Variance
APU	Auxiliary Power Unit
ATC	Air Traffic Controller
°C	degrees Celsius
CAE Inc.	simulator manufacturer (formerly Canadian Aviation Electronics)
CRT	Cathode Ray Tube
deg	degrees
DFW	Dallas Fort Worth
DOF	Degrees of Freedom
F	F ratio computed from a sample
°F	degrees Fahrenheit
FAA	Federal Aviation Administration
FD	Flight Director
ft	feet
g	gravitational constant
GS	Glide slope
Hz	Hertz
I/E	Instructor/Evaluator
in	inches
ILS	Instrument Landing System
LOC	Localizer
LOE	Line Oriented Evaluation
MANOVA	Multivariate Analyses of Variance
ms	milliseconds
MSL	Mean Sea Level
NASA ARC	National Aeronautics and Space Administration Ames Research Center
nm	Nautical Miles
n.s.	not significant ($p>.05$)
NSP	National Simulator Program
p	probability
PIA	Precision Instrument Approach
PF	Pilot Flying
PFQ	Pilot Flying Questionnaire
PNF	Pilot Not Flying
PNFQ	Pilot Not Flying Questionnaire
PTS	Practical Test Standards
r	Pearson's correlation coefficient
RMS	Root Mean Square
RTO	Rejected Takeoff
RVR	Runway Visual Range

s	seconds
SAS^{TM}	statistical analysis software
SMEs	Subject Matter Experts
STD	Standard Deviation
SSL	Sidestep Landing
V_1	Takeoff decision speed
V_2	Takeoff safety speed (minimum)
V_{mca}	Minimum control airspeed
Volpe Center	Volpe National Transportation Systems Center
V_R	Takeoff rotation speed
x_s	Surge
y_s	Sway
z_s	Heave
ϕ	Roll
θ	Pitch
ψ	Yaw
*	significant ($p<.05$)

EXECUTIVE SUMMARY

This report presents the results of two studies that examined the effect of enhanced hexapod-simulator motion on recurrent evaluation in the simulator, on the course of recurrent training in the simulator, and on "quasi-transfer" of this recurrent training to the simulator with motion as a stand-in for the airplane. These studies were conducted in the framework of the Volpe Center's Flight Simulator Fidelity Requirements Research Program and sponsored by the Federal Aviation Administration.

Today, airline pilots are almost exclusively trained and evaluated in flight simulators. That means that the first time a pilot flies a particular airplane or in a particular capacity in the air, the airplane is carrying paying passengers. It is therefore critical that, when evaluating a pilot in the simulator, the skills and behaviors comprising the expertise of this pilot when flying the airplane are accurately reflected in the simulator. Similarly, the skills and behaviors a pilot acquires in the simulator must transfer to the airplane. The definition of an effective simulator is therefore one that allows full transfer of performance and behavior from the airplane to the simulator for evaluation and from the simulator to the airplane for training.

The Federal Aviation Administration, who regulates simulator use for total training and evaluation of airline pilots, is responsible for ensuring that simulator requirements are sufficient for transfer of performance and behavior between airplane and simulator. To prevent simulator rental, acquisition, and maintenance costs from excluding smaller airlines from the benefits of simulator training and evaluation, however, requirements must also be necessary.

One requirement that remains controversial is the need for platform motion. Of course, the airplane does move; however, there are inherent limitations to the fidelity of the hexapod-motion platforms used for airline-pilot training. These motion platforms have been shown to be useful in some aerospace applications, but there is currently no empirical research that shows that platform motion improves transfer for airline-pilot training and evaluation. Studies to date have been limited by factors such as: (1) the quality of the available visual and motion systems, (2) the experience level of the subject population (e.g., studies often used novice pilots that may not yet have learned to capitalize on motion cues), (3) the number of subjects used, (4) the choice of maneuver selection (e.g., using tracking maneuvers that may not require motion cues), (5) individual differences in the pilot population, and (6) combinations of these factors (e.g., the number of pilots was not sufficient to wash out individual differences between pilots that could have masked the effects of motion).

Volpe was attempting to overcome these limitations by adopting a design philosophy using a simulator with a wide field-of-view visual system known to induce the illusion of motion (vection); testing experienced and highly motivated pilots that were asked to perform diagnostic pilot-in-the-loop maneuvers with asymmetric disturbances and high workload; and measuring at a high-sampling rate the motion-performance of the simulator, pilot flight-path precision, and pilot-control inputs. Also, any factors that could mask an effect of motion, such as between-group differences in experience, were minimized by calibrating the simulator, choosing a homogenous group of pilots, and counterbalancing across groups anything else that could not be controlled. A so-called quasi-transfer design was used to control many nuisance variables such as weather or traffic. In this design, pilots that came fresh from an airplane (to prevent adaptation to the simulator) were divided into two groups, a Motion and a No-Motion group. Pilots in both groups were first evaluated to measure transfer from the airplane. Pilots in the *Motion* group were then trained in the simulator *with motion* whereas pilots in the *No-Motion* group were trained in the simulator *without motion*. Following the training session, both groups were quasi-transferred to the simulator with motion as a stand-in for the airplane in order to compare the effect of the two training methods on transfer of training. Impostor effects that might masquerade as an effect of motion, such as rater or pilot bias, were avoided by concealing the purpose of the experiment and the motion condition (on or off) of the simulator from participants.

The first Volpe study (First Study) was aimed at testing the effect of "as is" motion, i.e., the motion provided by a qualified Level C simulator that is used around the clock for airline-pilot training and checking (Bürki-Cohen, Boothe, Soja, DiSario, Go, and Longridge, 2000; Go, Bürki-Cohen, and Soja, 2000). Because the initial concern was with the affordability of simulators for regional airlines, regional-airline crews were tested on a simulator of a 30 passenger turboprop airplane with wing-mounted engines. The data was collected from approximately 40 Captains flying engine failures on takeoff before their recurrent evaluation (V_1 cuts and rejected takeoffs).

No systematic differences between the two groups were found, during Evaluation, Training, and Quasi Transfer to all motion. This was true for the measurements from the simulator and for the grades provided by instructor/evaluators, and also for the crew and instructor opinions collected in extensive questionnaires. Power analyses showed that the number of pilots was sufficient to wash out individual differences between pilots, so that even small effects of motion could have been found.

Does this mean that "as is" motion is equivalent to having no motion with regard to transfer between simulator and airplane for recurrent evaluation and training? The failure-induced lateral acceleration of the "as is" motion simulator, which was supposed to serve as an alerting cue for the pilot that there was an engine problem, was found to be very mild, certainly milder than the one recommended based on the flight data. It was unclear whether this is typical for other simulators used in airline-pilot evaluation and training, and a comparison with eight airline simulators showed that it might be. This would lead to the conclusion that the requirements for airplane simulators used for airline-pilot training and checking should be tightened, and such efforts are currently being discussed by regulators and industry. Given the burden to the simulator operators to provide such motion and to the Federal Aviation Administration to enforce it, however, and the fact that airline pilots have been successfully trained and evaluated in simulators qualified under the current requirements for over twenty years, it seemed necessary to document that motion that was improved with tighter standards would result in improved transfer for airline-pilot simulator checking (evaluation) and training. This was the purpose of the Second Study, which is described in this report.

For this Second Study, the motion of a CAE Level D simulator was re-engineered to optimize the motion stimulation for the planned test maneuvers in collaboration with the National Aeronautics and Space Administration's Ames Research Center. The device simulates a Boeing 747-400 airplane with four wing-mounted engines. Its lateral acceleration and heave were enhanced trading off rotational motion (mainly yaw) based on findings in the literature. Forty current B747-400 Captains and First Officers participated, aided by two cohort pilots performing non-flying duties. The participants departed with an engine failure either just before (V_1 cut) or just after takeoff (V_2 cut), and then continued with either a precision instrument approach and landing with shifting crosswinds or a sidestep landing with a vertical upward gust just after sidestepping to a parallel runway. To make the maneuvers even more difficult (and participants subjective comments suggested that they did find them very difficult!), the autopilot and autothrottle were inoperative throughout and the flight director was inoperative during the landings only, so they had to be hand flown. These maneuvers were chosen to 1) replicate the V_1 cut tested in the First Study and 2) reduce any visual reference to the runway and require control in multiple axes compared to the First Study.

The results obtained with enhanced motion were very different from the First Study with "as is" motion. Several differences between the Motion and the No-Motion groups were found, and a fairly clear picture of the effect of motion emerges. First, motion did appear to alert pilots of a disturbance, as stipulated in the literature, but only for the V_1 cut. This may be because the V_1 cut occurs close to the ground and any delay in response would result in scraping the wings or the tail (which did happen, but equally rarely in the two groups, and usually because of applying the wrong rudder). Due to the motion alert, the Motion group had a faster pedal response and tracked heading slightly better, but the latter showed only during Evaluation. The No-Motion pilots, as long as they did not have the motion cue, were unable to significantly improve their pedal-response time, even during Training when they were told what failure to expect. Once they quasi-transferred to motion for Quasi-Transfer Testing however, their pedal-response time was identical to the one of the Motion group. Hence, the No-Motion pilots did not seem to need recurrent training with motion to be able to sense and appropriately respond to motion cues.

Second, training with motion cues clearly increased the control activity of the Motion pilots, especially for wheel inputs. However, this reduced their flight precision, at least for the landing maneuvers. These performance decrements in localizer, heading, or airspeed tracking were in fact the largest effects found in the study, and may be operationally relevant. Most importantly, the performance deficit of the Motion group persisted even when both groups had motion during Quasi-Transfer Testing.

Perhaps inherent to the increased control activity of the Motion group was a curious result found for the V_2 cut during Quasi-Transfer Testing, namely, that the Motion group responded slower to the engine failure than the No-Motion group, with apparently no effect on flight precision. One hypothesis is that the Motion group was fatigued. An alternative explanation is that both groups were equally fatigued and that the emergence of the motion cues may have had "stimulating" effect on the No-Motion group. Overall, the V_2 cut does appear to have been especially fatiguing for both groups, with several variables that had significantly improved during Training compared to Evaluation significantly deteriorating between Training and Quasi-Transfer Testing for both groups.

Third, motion affected the sidestep-landing strategy in a predictable manner. When motion was available, pilots landed softer. However, pilots also landed slightly farther from the runway threshold, but still well within the landing box. Like all effects on the landing maneuvers, this effect seems to have been consolidated during Training, because it persisted even during Quasi-Transfer Testing.

Finally, the results show that both groups improved their performance for all maneuvers in the course of the experiment, regardless of whether they were trained with or without motion. Initial Evaluation, however, was subject to motion effects for all four maneuvers, as discussed above.

These results were reflected in Pilot-Flying (PF) and Pilot-Not-Flying (PNF) opinions. The PFs found the simulator equally acceptable than their company simulator regardless of group. They were also equally comfortable in it. Moreover, there was no difference between groups with respect to their comparisons of the simulator to the airplane for Control Sensitivity and Control Strategy and Technique.

For all the in-depth probing, there were only four questions on which the two PF groups disagreed, and for one of these it was the No-Motion pilots that answered more favorably: After Training, the No-Motion group gave the simulator higher handling-quality ratings than the ones given by the Motion group. The ratings of the Motion group were higher than the ones of the No-Motion group for Control Feel (even at Quasi Transfer, when the No-Motion group also had motion), Other Cues (the majority of No-Motion pilots did recognize that something was amiss) and Performance (only after Evaluation).

The PNFs ratings always were in favor of the No-Motion group, but sometimes this was due to one of the two PNFs, while the other didn't always see a difference. They felt that the No-Motion pilots were more similar to the average pilot than the motion pilots with respect to Control Strategy and Technique (but not during Evaluation). They gave higher performance and lower workload ratings to the No-Motion pilots, except during Training. For Quasi Transfer only, they gave better Gaining Proficiency ratings to the No-Motion pilots.

In conclusion, this study showed that enhanced hexapod motion, configured based on the guidelines in the literature, does have an effect. It appears to affect the accuracy of recurrent evaluation. However, the benefits for recurrent training remain questionable.

Results of these studies and the previous hexapod motion research should assist the FAA in determining future research directions in the effort to develop improved motion standards. It also may contribute to finding a cost-effective solution to today's airline evaluation and training needs via an appropriate combination of fixed-base and motion-base simulators.

SIMULATOR PLATFORM MOTION REQUIREMENTS FOR RECURRENT AIRLINE PILOT TRAINING AND EVALUATION

1. BACKGROUND

The goal of this work is to enhance the safety of air travel by promoting the use of effective airplane simulators for airline-pilot training and evaluation. Over the past twenty-two years, transport pilots have come to be trained and evaluated almost exclusively in the simulator, so that the first time a pilot serves in a new position or in a new airplane type, the airplane will be carrying paying passengers. This is certainly true for all major airlines, and may become a fact for all airlines as a consequence of flight simulation device aviation rulemaking activities (see http://www.faa.gov/nsp/Part60_FTD.htm, accessed August, 2004, for more information).

Given that the practice of "total training and evaluation in the simulator" may become regulatory, the FAA is committed to ensure that flight simulators are both effective and accessible to all airlines. This must include regional airlines that find it cost-effective, for small airplanes with comparatively low operating cost and loss in revenue, to conduct some of their pilot training and evaluation in the air.

A simulator is effective if it supports full transfer of performance and behavior between simulator and airplane. That is, for effective training, any skills that pilots acquire in the simulator must be available to them in the airplane. Similarly, for accurate evaluation, the level of skills pilots display in the airplane must be reflected during evaluation in the simulator. Strategies and techniques as well as physical and mental workload of the pilots must also transfer between simulator and airplane.

Ideally the simulator systems must stimulate pilots as the airplane would. Only then the simulator will accurately represent all cognitive and motor challenges encountered in flight. However, not all stimuli encountered in flight may affect performance or behavior. And likewise, not all stimuli may need to be, or can be, presented exactly as they are encountered in flight. Some may have to be generated psychologically using different underlying physics than the ones present in the air, such as when the simulator tilts forward or backward to create the illusion of the negative/positive surge acceleration experienced during landing and takeoff. Similarly, the illusion of motion induced by the visual system, i.e., vection, may help compensate for some of the other limitations of a standard hexapod-platform-motion system in generating exactly the same vestibular stimulation experienced in the airplane (see also Roscoe, 1991).

FAA regulations therefore must be sufficient to ensure that all stimuli necessary for full transfer of performance and behavior between simulator and airplane are presented. However, they also must be necessary, i.e., they should avoid requiring stimuli with no operationally relevant effect on training and evaluation outcomes, because this would unnecessarily reduce the availability of qualified simulators. To achieve this goal, the FAA asked the Volpe National Transportation Systems Center (Volpe Center) to review the FAA's flight simulator fidelity requirements as outlined in Advisory Circular AC 120-40B (FAA, 1991). The initial focus of this research was recurrent evaluation.

2. REQUIREMENTS REVIEW: INITIAL FINDINGS AND RESEARCH QUESTIONS

2.1 Subject Matter Expert Opinion

As a first step, Volpe organized a series of joint FAA-industry symposia on the most costly aspects of airplane simulation attended by subject matter experts (SMEs) from industry, academia, and FAA (Longridge, Ray, Boothe, and Bürki-Cohen, 1996). These led to a focus on platform motion, which is mandatory for simulators used as the sole means for training and evaluation. The participating SMEs in the symposium on simulator motion generally perceived that the absence of platform-motion cueing in fixed-base devices is likely to have a detrimental effect on pilot control performance, particularly in maneuvers with an external disturbance entailing sudden motion-onset cueing with limited visual reference. It was also noted, however, that there was no scientific evidence that training in a fixed-base device would lead to degraded control performance in the actual aircraft (Bürki-Cohen (Ed.), 1996). This issue is especially pertinent in a device equipped with a wide field-of-view visual system, which can generate an illusion of motion (vection) (Young, 1978), albeit with a slower onset than vestibular motion.

2.2 Literature Review

An extensive literature review (Bürki-Cohen, Soja, and Longridge, 1998) confirmed that platform motion in the simulator might improve the perceived acceptability of the simulator, at least when the pilots were aware of the motion manipulation (Reid and Nahon, 1988; but see Bussolari, Young, and Lee, 1987). Motion also improved pilot performance and control behavior in the simulator, especially for tasks with an external disturbance or tracking tasks in aircraft with low dynamic stability (Hall, 1978; Hall, 1989; Hosman and van der Vaart, 1981). Some of the benefits of platform motion have also been shown to transfer to a higher-fidelity simulator (Levison, 1981). However, the literature review also showed that the benefits of platform motion have not been proven in the case of transfer of training to the airplane (see, e.g., Waag, 1981).

In conclusion, many experts believe that the simulator should provide all cues that a pilot experiences in the airplane. For motion, however, the actuator travels and filter algorithms typical for the type of simulators accessible to airlines severely limit the ability to fully match the magnitude and phasing of the cues experienced in the air. This may have been one of the reasons why none of the earlier studies has been able to demonstrate an effect of motion on transfer of skills to the airplane. Motion systems have been greatly improved, however, since these studies were conducted, and so has the ability to avoid other flaws in the experimental design.

The FAA asked Volpe to revisit the question of simulator motion empirically, using a rigorous research design and data analysis process and state-of-the-art motion and visual systems. Questions to be answered include, but are not limited to, the following: Are there any flight tasks for which a measurable difference in simulator training and evaluation effectiveness can be found with and without platform motion? What is the relationship in motion-cueing effectiveness for a wide field-of-view visual display versus platform motion? Are current platform-motion qualification criteria optimal? Is there a relationship between pilot experience level and the effectiveness of platform motion for training?

3. EMPIRICAL RESEARCH

3.1 Research Approach

The research approach adopted by the Volpe Flight Simulator Fidelity Requirements Research Program is illustrated in Figure 3-1. First, it is necessary to establish that the type of motion that is currently used by airlines has an operationally relevant effect on recurrent training and evaluation. This test is performed on a turboprop airplane simulator used round-the-clock by regional airlines. The rationale for this is that some regional airlines do not have ready access to qualified simulators with motion systems, and many conduct at least some of their recurrent training in the airplane. This deprives them of the benefits of safely practicing carefully constructed emergency scenarios in the simulator. It is therefore necessary to establish that the benefits from experiencing motion outweigh the cost of this loss in training opportunities.

If no operationally relevant effect of motion was found with such a “typical” motion system, the next step was to test whether the standard Stewart hexapod-platform-motion systems available to airlines can be re-engineered so as to produce an operationally relevant effect of motion. Other aspects of the experiment may be modified as well to enhance the possibility of finding an effect of motion.

If still no operationally relevant effect of motion is found, the next step will be to test whether the previous finding that motion has no effect on training transfer and evaluation extends to initial training of airline pilots. Another question may be the role of motion in maneuvers where pilots must learn to ignore motion cues, such as when vestibular motion perception leads to dangerous illusions with regard to the airplane’s attitude.

Whenever an operationally relevant effect of motion is found, however, the next logical step will be to develop comprehensive motion qualification criteria. Current regulations, although they do require the presence of motion for certain types of training and evaluation, do not provide a means to objectively assess the quality of such motion (Lahiri, 2000). For this purpose, the nature of effective motion cues and which maneuvers are sensitive to them and why must be determined.

To prevent that such tightened motion standards limit access to simulators, it will also be important to examine whether there are alternative means than full six-degree-of-freedom platform motion to provide effective motion cueing, such as providing motion onset cues with vibration and dynamic seats.

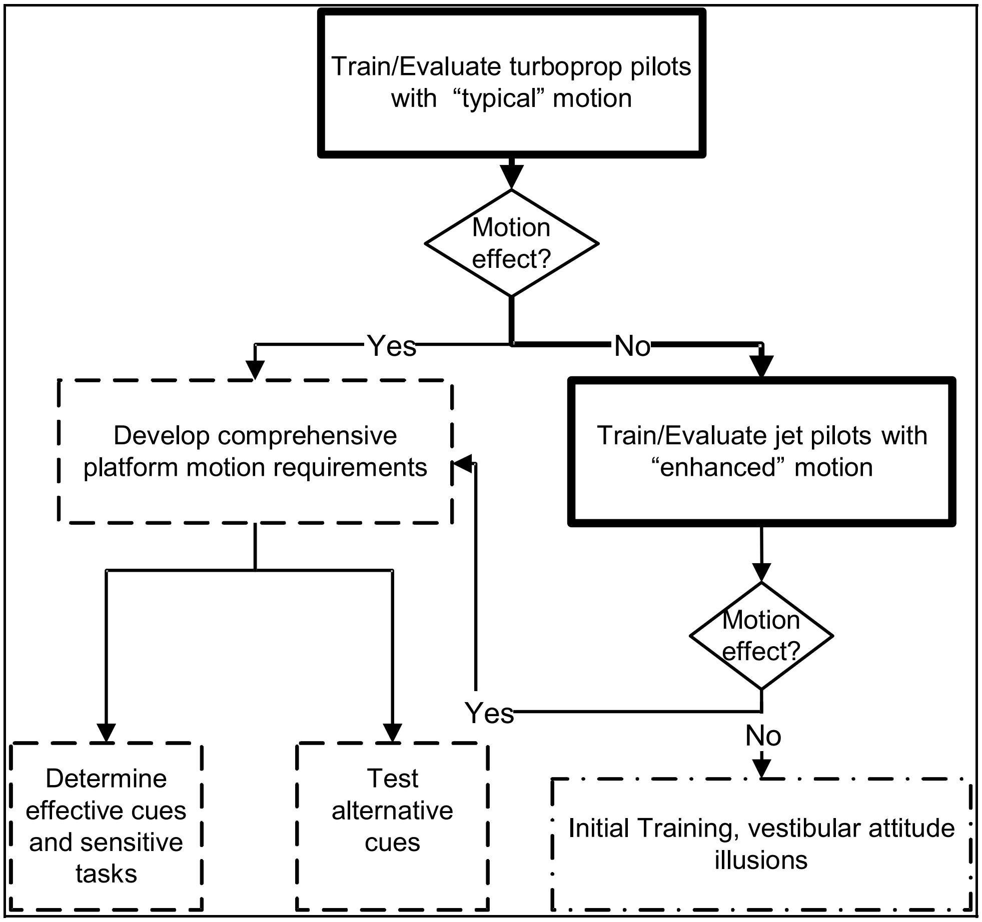


Figure 3-1. Research Approach to Determine Motion Requirements

3.2 Research Strategy

The research strategy adopted in this work is very much informed by the fact that previous attempts to show an effect of simulator motion on transfer to the airplane have failed. Most of the studies testing transfer of training to the airplane suffer from the use of now outdated motion systems, the possibility of pilot and rater bias, insufficient measurements and statistical power, and the use of maneuvers for which motion may not be important. In this work, everything possible will be done to magnify any positive evidence for an effect of motion that may exist, and to avoid any spurious effects due to factors other than motion.

3.2.1 Magnify Any Existing Evidence For An Effect Of Motion

It is much more convincing to reject a null hypothesis, such as "simulator motion has no effect on transfer between airplane and simulator," based on positive evidence for a motion effect, than to accept it when no evidence for a motion effect is found. Therefore, this research program will use the following tactics to prevent that an effect of motion is overlooked:

- Compare pilot performance and behavior between extreme conditions, i.e., in a Level C/D motion simulator vs. the fixed-base simulator

- Use subjects and maneuvers that are described in the literature as susceptible to feedback from vestibular motion cues rather than from vection arising from visual cues, namely, experienced pilots and skill-based disturbance maneuvers
- Measure or record at high sampling rates any variables and parameters that are potentially useful to assess pilot performance and workload
- Ensure sufficient statistical power of the experiment, i.e., test enough subjects to wash-out unavoidable within-group differences that might mask an effect of motion

3.2.2 Avoid Spurious Effects

Spurious effects due to factors other than motion that may either impersonate or camouflage an effect of motion will be avoided using the following tactics:

- Counterbalance or randomly assign participants to groups to minimize any known or unknown between-group subject variables
- Prevent variability in pilot stimulation and measurement error by calibrating the simulator systems (motion, force feedback, visual system, sound, etc.) and measurement systems regularly before, during, and after data collection
- Counterbalance any other uncontrollable variables
- Conceal the motion status of the simulator to prevent participant bias
- Use a quasi-transfer paradigm, where the simulator with motion is used as a stand-in for the airplane during transfer testing, to avoid other uncontrolled variability such as weather and traffic

4. FIRST STUDY

4.1 Research Question

Following the research plan shown in Figure 3-1, the First Study investigated the effect of "typical" motion on recurrent training and evaluation of regional airline pilots in the presence of a wide field-of-view visual system (Bürki-Cohen et al., 2000; Bürki-Cohen, Soja, Go, Boothe, DiSario, and Jo, 2001; Go et al., 2000).

4.2 Method

The experiment used an FAA qualified Level C flight simulator of a 30 passenger, three crew, turboprop airplane with wing-mounted twin engines and counter-rotating propellers. The six-degree-of-freedom synergistic motion system had hydraulically actuated legs capable of a 60-inch stroke. The high quality visual system provided wide angle collimated cross-cockpit viewing with a 150 degrees horizontal and 40 degrees vertical field of view available to each pilot.

The subjects of the experiment were experienced regional-airline captains. Half of the captains were first evaluated and trained with and the other half without motion. Then the transfer of the skills acquired by both groups during Evaluation and Training was tested in the simulator with the motion system turned on as a stand-in for the airplane (Quasi-Transfer Testing). The test maneuvers selected were engine failures on takeoff with either rejected takeoff (RTO) or continued takeoff ($V_{1/R}$ cut) with a quarter mile Runway Visual Range (RVR) and 10 knots crosswind, which satisfied the criteria described in the literature as diagnostic for the detection of a motion requirement. These criteria included:

- Skill- instead of procedure-based, to increase reliance on motion feedback (Hosman, 1999)
- Closed loop, to allow for motion to be part of the control-feedback loop to the pilot
- Disturbance maneuver, to highlight an early alerting function of motion (Gundry, 1976; Hall, 1989)
- High gain, to magnify any motion effects and to reduce the stability of the pilot-airplane control loop (Hall, 1989)
- High workload with crosswind and low visibility, to increase the need for redundant cues such as provided by motion, out-the-window view, instruments and sound
- Short duration, to prevent pilots from adjusting to a lack of cues

Neither the captains, nor the not-flying co-pilots, nor the instructors/evaluators (I/Es) knew the purpose of the experiment or the motion status of the simulator.

4.3 Procedure

First, the crews flew one V_1 cut followed by one RTO (Evaluation). Half of them did it with the motion system on (Motion group) and the other half with the motion system off (No-Motion group). Any additional training needed to reach the company standards for RTO and V_1 cut came next, with motion on or off depending on group. At most, there were two additional training trials for each type of maneuver. After Training, all participants filled out a questionnaire. This was followed by two normal takeoffs with the same motion configuration. Then the crews flew one last V_1 cut followed by one last RTO with motion on for all crews (Quasi-Transfer Testing). After Quasi-Transfer Testing, all participants filled out a second questionnaire, to see whether their opinions had changed after all had experienced motion. The engine-failure side was randomly varied during the course of the experiment.

Phase I: Evaluation/First Training

- Evaluate V_1 cut
- Evaluate RTO

Phase II: Training

- Train to criterion, or a maximum of additional 2 V_1 cuts and 2 RTOs
- Perform 2 normal takeoffs as a distraction

PF and PNF complete Questionnaire 1

Phase III: Quasi-Transfer Testing

- Quasi Transfer to motion V_1 cut
- Quasi Transfer to motion RTO

PF and PNF complete Questionnaire 2

The stimulation of the PF by the simulator, pilot-vehicle control performance, and pilots' responses were measured by recording 78 simulator state and control-input variables at a 50 Hz sampling rate, resulting in a vast amount of objective data on simulator performance and pilot performance and behavior/workload. Two forms of subjective data were also collected. First, at the conclusion of each maneuver the I/E provided a grade for the just-completed maneuver. Second, as already mentioned in the previous paragraph, at the end of the training phase and again at the end of the Quasi-Transfer phase all participants were queried on PF performance and workload as well as simulator comfort and acceptability. From all these data, four types of results were obtained:

- Motion stimulation at the PF station
- Effect of motion and experiment phase on measured performance and workload of the PFs, either as a group or individually
- Effect of motion on the performance of the PFs as perceived by the I/Es and reflected in their grading
- Effect of motion on participants opinion regarding PF performance/workload and simulator comfort and acceptability

4.4 Results

Multivariate analyses of variance (MANOVA) determined the Group and Phase effects on the pilot performance and behavior (see 5.3.3.2 for an explanation of analysis procedures). Sufficient statistical power was ascertained by calculating the minimum difference between the standardized means leading to the rejection of the null hypothesis with a probability of .80 (effect size). Table A1-1 in 1 summarizing the Group and Phase effect sizes of several important variables shows that the analyses performed could detect sufficiently small Group or Phase differences to capture operationally relevant effects.

4.4.1 Test Simulator Motion Performance

For the test simulator, the actually measured roll and longitudinal accelerations followed the airplane model fairly well given the limitations inherent to all simulators. For vertical acceleration, however, the motion system of the test simulator did not respond much to the command provided by the equations of motion. This was especially true for V_1 cut maneuvers. However, because the engine failures used in our experiment do not produce much vertical acceleration, the lack of vertical acceleration cueing may not be very important.

More important, however, is the finding that failure-induced lateral acceleration was not well represented by the motion system of the test simulator (see Table A1-7 in 1.5). Not only was it greatly attenuated, but visual inspection of the measured response did not lead to an easy distinction of failure-induced lateral acceleration, unlike the response derived from the equations of motion (relatively high peak shortly after engine failure). This may represent a significant deficiency in pilot stimulation, because lateral acceleration may act as a useful cue for proper failure recognition and for initiation of appropriate response.

4.4.2 Pilot Performance and Behavior

The results of the study indicate that the motion provided by the test simulator did not, in an operationally significant way for the tasks tested, affect evaluation, training progress, or quasi transfer to the simulator with motion of the training acquired in the simulator with or without motion. It also didn't consistently affect the Pilots' Flying (PF), Pilots' Not Flying (PNF), and instructor/evaluator's perception of the PFs' performance, workload, and training progress, or of their own comfort in the simulator. Neither did it affect the acceptability of the simulator to the PF and the PNF. Details of these results are given in 1 and will be discussed further in comparison with the results of the Second Study (Section 5.3).

4.5 Discussion

There are several questions that can be raised regarding the validity of these results, which will be answered in turn below.

First, it was found that the lateral acceleration produced by the simulator shortly following the engine failure was greatly attenuated compared to the lateral acceleration from the aircraft mathematical model. This suggests that the simulator used in the study may not have provided sufficient motion stimulation to the captains to produce an effect. The first response to this objection is that the test simulator was FAA qualified and used 20 out of 24 hours daily for pilot training and evaluation. So, it cannot be excluded that the motion stimulation produced by this simulator may be representative for at least some of the simulators in service. With help from the National Simulator Program Office (NSPO), data from eight other simulators representing aircraft with wing-mounted engines were gathered. Initial evaluation was done on those sets (Boothe, 2000), but unfortunately, only four sets were available for further examination. 1.5. Comparison of Failure Induced Lateral Acceleration in 1 summarizes the findings from these comparisons, including the test simulator. The results indicate that the motion-system performance of the test simulator was not atypical. One major question to be answered in the Second Study, therefore, is whether standard hexapod-motion systems can be tuned so that they provide motion that is representative enough to affect continuing qualification of airline pilots.

A second question is whether the regional-airline Captains were experienced and motivated enough. In response to this question, it must be noted that the short-haul operations of a regional airline require these captains to fly many takeoffs. Moreover, not one of the approximately 300 takeoffs in the experiment resulted in a crash (compare with the Success Rates in the Second Study given in 5.3.2, which tested very senior pilots flying long-haul operations across continents). With regard to the captains' motivation, they were tested by the same instructor/evaluator that would grade them during their recurrent evaluation immediately afterwards, when their job was in jeopardy. It is safe to assume that they were motivated to make a good initial impression.

A third question is whether the takeoff maneuvers tested were sensitive enough to detect a need for motion. As laid out in Method, both $V_{1/R}$ cuts and RTOs fully satisfy the criteria laid out in the literature. However, although the maneuvers were flown at the lowest legal RVR, there may have been some residual visual reference to the runway centerline, which may have helped the pilots control their flight path even without motion cues. This may have been true even for the $V_{1/R}$ cut, because in the airplane configuration tested, the takeoff decision speed V_1 and rotation speed V_R were identical. Also, although the two maneuvers perfectly fulfill the three criteria of unpredictability, asymmetry, and short duration, a longer lasting maneuver may be needed to let a measurable motion advantage develop. These considerations will be taken into account when choosing the maneuvers for the Second Study.

The last concern regarding the validity of the results of the First Study is that quasi transfer to the simulator with motion as a stand-in for the airplane was tested instead of transfer to the airplane itself. The first response to this concern is that after years of successful total training and checking in the simulator with motion, the simulator with motion has been validated as a stand-in for the airplane. Second, if motion really makes a difference, then pilots trained in the simulator without motion should perform differently when motion is turned on compared to pilots that were trained under exactly the same configuration that they are being tested in. Third, it would be impossible to design a valid and reliable experiment transferring to the airplane. This is because, on the one hand, sensitive maneuvers would be too dangerous to test in the air. On the other hand, it would be impossible to control for unpredictable environmental nuisance variables such as weather and traffic.

5. SECOND STUDY[1]

5.1 Introduction

Based on the work described in the previous sections and a growing awareness that the motion requirement needs to be better defined, an ongoing international effort aims at tightening motion standards (see, e.g., Lahiri, 2000). Such standards, however, would represent a considerable burden for both simulator users and simulator regulators. Users would face increased leasing, purchasing, and maintenance costs, as well as loss of training opportunities, e.g., when the simulator motion is malfunctioning and crews have to be sent home. The FAA would need to increase its resources to enforce the tighter standards. Prudence would dictate to first show that tighter motion standards increase the training and evaluation value of simulators sufficiently to increase passenger safety before changing the standards.

The purpose of the Second Study is to test whether the Results of the First Study extend to a high-quality research simulator with its six-degree-of-freedom hexapod re-engineered so as to maximize motion cues and phase match for each of the maneuvers tested. Simultaneously, any other potential reasons for the absence of a motion effect mentioned in the Discussion of the First Study will be avoided as much as possible. To achieve this, the maneuver range will be expanded based on recommendations from the literature and the FAA's National Simulator Program (NSP). In addition to replicating the V_1 cut, they will now include engine-out landings with weather requiring very tight multi-axes flight-path control and a V_2 cut providing no visual reference to the runway

[1] Preliminary results of this study have been published in Bürki-Cohen, Go, Chung, Schroeder, Jacobs, and Longridge (2003) and Go, Bürki- Cohen, Chung, Schroeder, Saillant, Jacobs, and Longridge (2003)

centerline. Again, experienced pilots will be used, namely, pilots qualified on the Boeing 747-400. Pilots will be motivated to keep tightly in the control loop by providing feedback displays on their flight-path precision on the navigation display. The quasi-transfer paradigm will be maintained to preserve control over variables such as weather and traffic.

5.2 Method

For the general strategy and tactics guiding the design of this experiment, see the overall Research Strategy described earlier.

5.2.1 Experiment Design Overview

Participants serving as Pilots Flying (PF) were divided into two groups: Motion and No-Motion (between-subjects design). In Phase I and Phase II, i.e., Evaluation and Training, the Motion group was evaluated and trained in the simulator with motion. The No-Motion group was evaluated and trained in the simulator with the motion system turned off. Both groups were then quasi-transferred to the simulator with motion as a stand-in for the airplane to examine whether any effect of motion during Training would persist in the airplane (Phase III, Quasi-Transfer Testing).

This design resulted in two independent variables, the Group variable with two levels (Motion group and No-Motion group) and the Phase variable with three levels (Training, Evaluation, and Quasi-Transfer Testing). Participants belonged to either the Motion or the No-Motion group, but all participants were subjected to the three phases. The dependent variables were derived from over 100 variables, from which the directional, lateral, and longitudinal pilot-vehicle performance and pilot control-input behaviors appropriate for each maneuver were calculated. PFs and Pilots Not Flying (PNFs) also provided their opinions in detailed questionnaires.

Precautions were taken to assure that no effects were overlooked or, conversely, emerged as a result of nuisance variables unrelated to the independent variables. First, quasi transfer to the simulator with motion, instead of real transfer to the airplane, kept constant any extraneous variables other than motion that could affect PF performance and behavior (e.g., weather and traffic). Quasi transfer to the simulator also removed any restrictions on the maneuver choice due to safety reasons. Also, PFs were randomly assigned to the Motion or No-Motion group, provided that they were equally distributed across groups with respect to seat, PNF, and experience (number of landings in the past 12 months). To prevent bias, the purpose of the experiment was concealed from the PFs. Finally, simulator-calibration checks were performed before each experiment run to ensure the consistency of all functions.

5.2.2 Environmental Variables and Maneuver Choice

The maneuvers were selected from the most critical phases of flight, namely, takeoff and landing. Each engine-out takeoff maneuver was paired with a landing maneuver into one scenario. All maneuvers were tailored to satisfy the criteria listed in the Method of the First Study. To include the engine-out landing maneuvers mentioned in the Introduction to this study, however, the short-duration criterion to prevent pilot adaptation had to be relaxed. To reduce the visual reference during the V_R cut even further, the engine was failed at a specified height Above Ground Level (AGL), resulting in an engine failure after V_2 (V_2 cut).[2] To be able to compare the results of this study with the First Study, the V_1 cut was maintained as a test maneuver. The Pilot-Not-Flying declared the engine failures as not recoverable. As in the previous experiment, maneuvers and airport/meteorological conditions were chosen to correspond as much as possible, while being a good diagnostic tool for detecting the effect of motion, to real-life simulator training and evaluation. They are based on the FAA Practical Test Standards (PTS) (FAA, 2001). The environmental conditions and the maneuvers are described in detail below.

5.2.2.1 Airport, weather and airplane variables

Dallas Forth Worth (DFW) airport was chosen for its configuration and for its presumed equal familiarity to potential study participants.

A light simulated-aircraft gross weight of 550,000 lbs was intended to increase the handling difficulty and motion cues of the simulator during the test maneuvers. Pilots were told that the fuel would remain constant at 60,000 lbs. To further increase pilot workload, the autothrottle was inoperative throughout the experiment.

5.2.2.2 Continued takeoffs with engine failure

In these maneuvers, an outboard engine failure occurred after V_1 had been reached and the takeoff must be continued. The failure represented an engine flame-out with failure profile showing exponential loss of 90% of initial thrust in about two seconds.

All takeoffs occurred from runway 36 Right at an altimeter altitude reading of 29.92 inches of mercury. There was a constant 10-knots tailwind. The runway visible range was 600 ft with fog top height of 500 ft. The sky conditions were overcast, with broken clouds at 3000 feet.

The engine-failure triggering variables were varied to generate two maneuvers with different visual reference, motion stimulation and workload as described below.

Takeoff with engine failure after V_2

For the V_2 cut, an outboard-engine failure was triggered after V_2 (150 knots) at 40 feet AGL. Because the airplane was pitched up at this point in the takeoff envelope, pilots could no longer refer to the runway visually and had to fully rely on their instruments and motion perception, if available. Compared to earlier engine failures where the wheels are still on the ground or the airplane is just rotating, pilots need to control pitch in addition to heading, resulting in high workload.

Takeoff with engine failure after V_1

For the V_1 cut maneuver, an outboard engine was failed when the simulator reached the minimal controllable airborne speed V_{mca} (124 knots). Compared to a V_2 cut, fewer axes need to be controlled when the wheels are still on the ground, but the asymmetry introduced by the engine failure is larger than at higher speeds. Moreover, application of

[2] Please note that in the questionnaires, the V_2 cut was described as a V_R cut.

the rudder is less effective at a lower speed. Finally, fast action is critical to avoid contact with the ground. Other reasons to replicate the V_1 cut in this study included the ability to compare it with the V_1 cut tested in the First Study and the fact that it is an integral part of any simulator qualification ride.

5.2.2.3 Engine-out landing maneuvers

Both landing maneuvers included an outboard-engine failure and were hand flown without autothrottle, autopilot, and FD. Both require the pilot to tightly control the simulator in all three translational (sway, surge, heave) and rotational (pitch, roll, sway) degrees of freedom. Under these circumstances, it was expected to be difficult, without motion feedback, to follow a narrow flight path and land softly in a tight box, especially with weather disturbances added to divert from the flight path.

Precision Instrument Approach

The NSP recommended a hand-flown out-board engine-out Precision Instrument Approach (PIA) with shifting crosswind as particularly hard to fly without motion feedback. This maneuver consisted of landing the airplane on runway 36 Left guided by the Instrument Landing System (ILS, localizer and glide slope). The visibility was kept low with 500 ft cloud ceiling and 5200 ft RVR.

A disturbance from a 10-12 knots terminal area crosswind shifting counterclockwise from a 310 degrees quartering headwind at 3500 ft Mean Sea Level (MSL) to a 220 degrees quartering tailwind on the ground added to the challenges of this hand-flown approach and landing. During training, when Engine 4 was failed instead of Engine 1, the wind shifted clockwise from 40 degrees to 130 degrees to maintain the symmetry of the task.

Sidestep Landing with vertical upward gust

White (1994) used an offset approach followed by an S turn onto the runway at a very low altitude "to generate the kind of high-gain pilot behaviour which is necessary to bring out vehicle or simulator deficiencies." Sidestep-Landing (SSL) maneuvers with a vertical upward gust have a long history of use (see, e.g., Schroeder, Chung, Tran, Laforce, 1998, based on Bjorkman, 1986). In the current study, the pilot had to switch landing from runway 36 Left to the 1200 ft (measured from centerline to centerline) apart parallel runway 36 Right at the relatively low altitude of 1000 ft AGL The visibility was 5 miles with a cloud ceiling of 1100 ft.

The wind was a constant 10 knots at 310 degrees, with the exception of a vertical upward gust peaking at 25 ft/s applied on the runway rollout to increase the workload of the pilot during this critical phase of the maneuver. As shown in Figure 5-2, the gust profile started at 2.15 nautical miles (nm) from the runway 36 Right threshold (measured along the runway centerline) and peaked at an altitude of 25 ft/s between 2.05 and 2 nm from the threshold. By 1.95 nm from threshold, the gust had completely died down. The gust was programmed so that all pilots would experience the same wind strength regardless of their lateral deviation from the runway centerline.

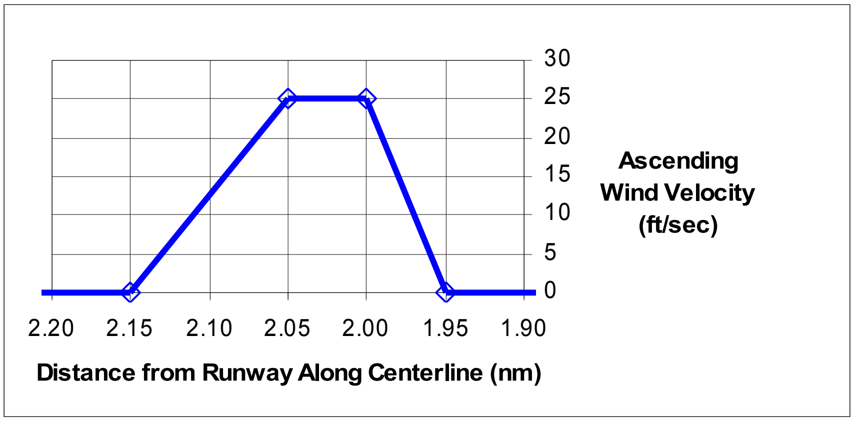


Figure 5-2. Vertical Upward Gust Profile during SSL

5.2.3 Simulator

The FAA-NASA (National Aeronautics and Space Administration) Ames Research Center (ARC) Boeing 747-400 simulator was used in the experiment. It was manufactured by the Canadian company CAE and FAA qualified at the Level D (FAA, 1991).

The main characteristics of the B747-400 simulator were:

- Four engines
- Glass cockpit with six cathode ray tube (CRT) displays:
  1. Primary Flight Display (PFD) Captain
  2. PFD First Officer
  3. Navigational Display Captain
  4. Navigational Display First Officer
  5. Engine Indication and Crew Alerting System (EICAS) displays in the middle. During the experiment, the EICAS Displays were in Primary Engine Indications and Secondary Engine Indications mode (as usual). This gave the crew a real-time indication using graphical gauge representation of the engine parameters. The graphical representation made it easy for pilots to see which engine was failed.

5.2.3.1 Visual system

The simulator was equipped with a FlightSafety Vital 8i visual system with the following capabilities:

- A wide field-of-view (180 degree horizontal and 40 degree vertical) uninterrupted panoramic out-the-window scene with cross-cockpit viewing
- High brightness and resolution, permitting high ambient lighting in the cockpit without washing out the scene or causing unwanted reflections
- Geo-specific, full color texture that greatly enhanced scene realism
- Over 2000 texture patterns available on-line simultaneously

- General transparency that enhanced cloud simulation
- Up to 2500 polygons and 1000 light points per channel processor in day mode; 5000 light points in dusk and night modes
- Landing-light simulation that gave roll and pitch cues. Lobe shafts in fog were also simulated.

5.2.3.2 Sound system

The simulator was equipped with a multi-channel and multi-speaker sound system. Simulation of aircraft sounds was realistic to the degree that direction as well as frequency and amplitude were represented. Sound data was compiled from high-quality tape recordings supplied as part of the approved data package.

Sound simulation was automatic and included, e.g., the following effects:

- Power plant sounds covered the whole operating range and varied according to pressure, altitude and airspeed. Simulated engine sounds represented acceleration, reverse sounds, engine surge, compressor stall, fan noise, engine seizure, turbine whine and rumble.
- Aerodynamic hiss varied as a function of airspeed, cabin differential pressure, altitude, sideslip, turbulence, and was modified as applicable by the use of flaps, slats, spoilers, landing gear, and landing gear doors.
- Runway effects and taxi rumble sounds reflected taxiing, takeoff and landing noise for the specified levels of runway roughness. Taxi rumble varied as a function of speed, runway roughness, and load on the nose wheel. Special sounds were provided for sliding after gear collapse.
- Sounds produced by pneumatic and electrical ground power units, Auxiliary Power Unit (APU) operation, hydraulic pumps, air-conditioning airflow, generator relays or other relay switching sounds, windshield wipers, nose gear up lock
- Special effects, such as cabin explosive decompression, tire burst, crash, rain, hail and thunder

5.2.3.3 Control loading

An advanced fully digital hydrostatic control loading system provided the following accurate control-feel cues as necessary for FAA Level D qualification:

- Elevators (dual load units: Captain, First Officer)
- Ailerons (dual load units)
- Rudder
- Nose wheel steering (dual load units)
- Brake pedals (dual load units)

The simulation included appropriate pilot forces and surface deflections. Powered operation was simulated including the effects of aerodynamic forces on the control surfaces. The simulation included accurate reproduction of the following effects as applicable:

- Inertia forces
- Frictions (coulomb and viscous)
- Breakout forces
- Centering spring forces
- Surface blowdown and float
- Aerodynamic forces and q-feel forces
- Bob weight
- Cable stretch
- Loss of hydraulic pressure
- Autopilot control and manual override
- Deadband
- Trim position and rates
- Pilot forces
- Velocity limits
- Travel limits

5.2.3.4 Motion system

The motion system of the test simulator was a 48-inch-stroke hexapod platform with allowable travel of 40 inches for each actuator. The dynamic characteristics of this motion platform met FAA Level D requirements of visual/motion cueing transport delay and bandwidth as shown in Figure 5-3 and Figure 5-4, respectively.

The top curve in Figure 5-3 shows how the back-driven column was manipulated during the test duration to initiate a pitch command. The middle curve shows the pitch-accelerometer response from the simulator. The bottom curve shows the video-signal response due to the pitch command. The transport delays for the motion and visual cues are measured from the initiation of the column command to the motion-system response and the visual-system response. Figure 5-3 indicates that there were a 92.4 millisecond (ms) transport delay in the motion-system response and 130.8 ms transport delay in the visual-system response. Both transport delays comply with the AC 120-40B's (FAA, 1991) performance guideline of 150 ms.

Figure 5-4 shows the acceleration frequency response of the motion system in heave, which indicates that the B747-400 simulator had sufficient bandwidth (9 Hz at 90 degree phase lag) to produce desirable dynamic responses.

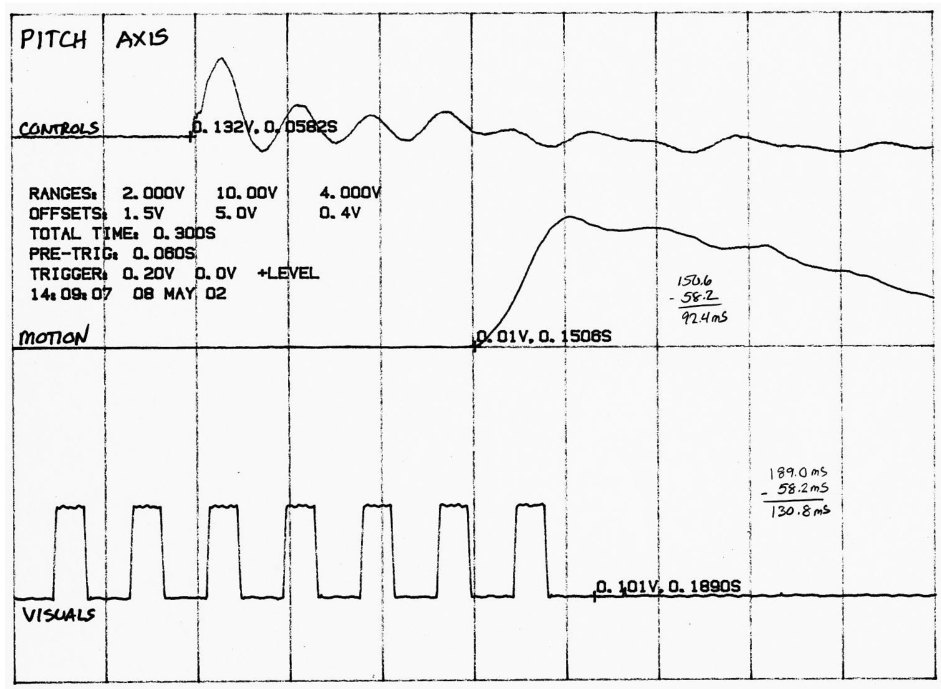


Figure 5-3. B747-400 Simulation Cueing Transport Delay Response

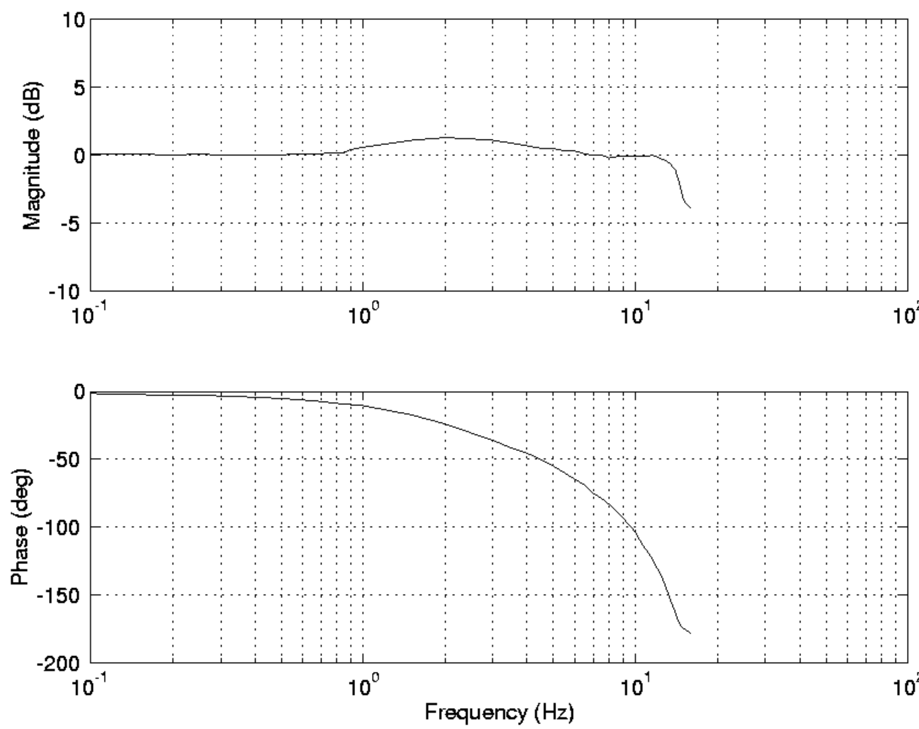


Figure 5-4. B747-400 Heave Acceleration Frequency Response

Figure 5-5 illustrates how motion cues are generated for typical ground-based flight simulators. The motion-drive algorithms generate motion-system travel commands corresponding to the airplane states at the pilot station. The motion system follows the motion commands and produces motion cues that pilots perceive in the cockpit. The dynamic characteristics of the motion-drive algorithms and the motion system, therefore, dictate the fidelity of the perceived motion cues.

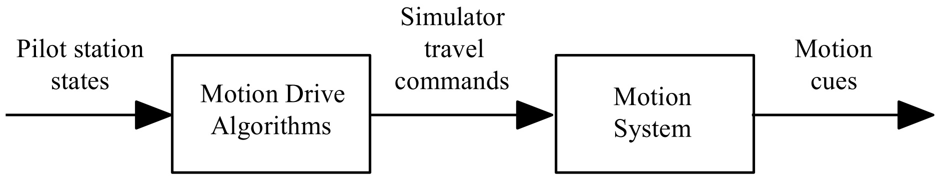


Figure 5-5. A Typical Motion-Cueing Generation Process For Ground-Based Flight Simulators

The B747-400 simulator at NASA ARC employed a common motion-drive algorithm as shown in Figure 5-6. The translational motion commands are functions of three translational washout filters, i.e., longitudinal, lateral, and vertical, and respective motion-command gains. This is shown in the top row of the diagram, where aircraft acceleration at the center of gravity (a_{cg}) is transformed, scaled, limited, high-pass filtered and twice integrated (shown in Laplace transform) to eventually result in simulator surge (x_s), sway (y_s), and heave (z_s). The angular motion commands are functions of three angular washout filters, i.e., roll (ϕ), pitch (θ), and yaw (ψ), and corresponding motion command gains. This is shown in the bottom row of the diagram, where the input from the aircraft model is angular rate ($\omega_{a/c}$) and thus needs to be integrated only once. All six motion-command gains are adaptive according to the travels, rates, and accelerations. Low-frequency surge and sway specific forces are generated by tilting the motion system in pitch or roll axis, respectively. This is shown in the middle portion of the diagram.

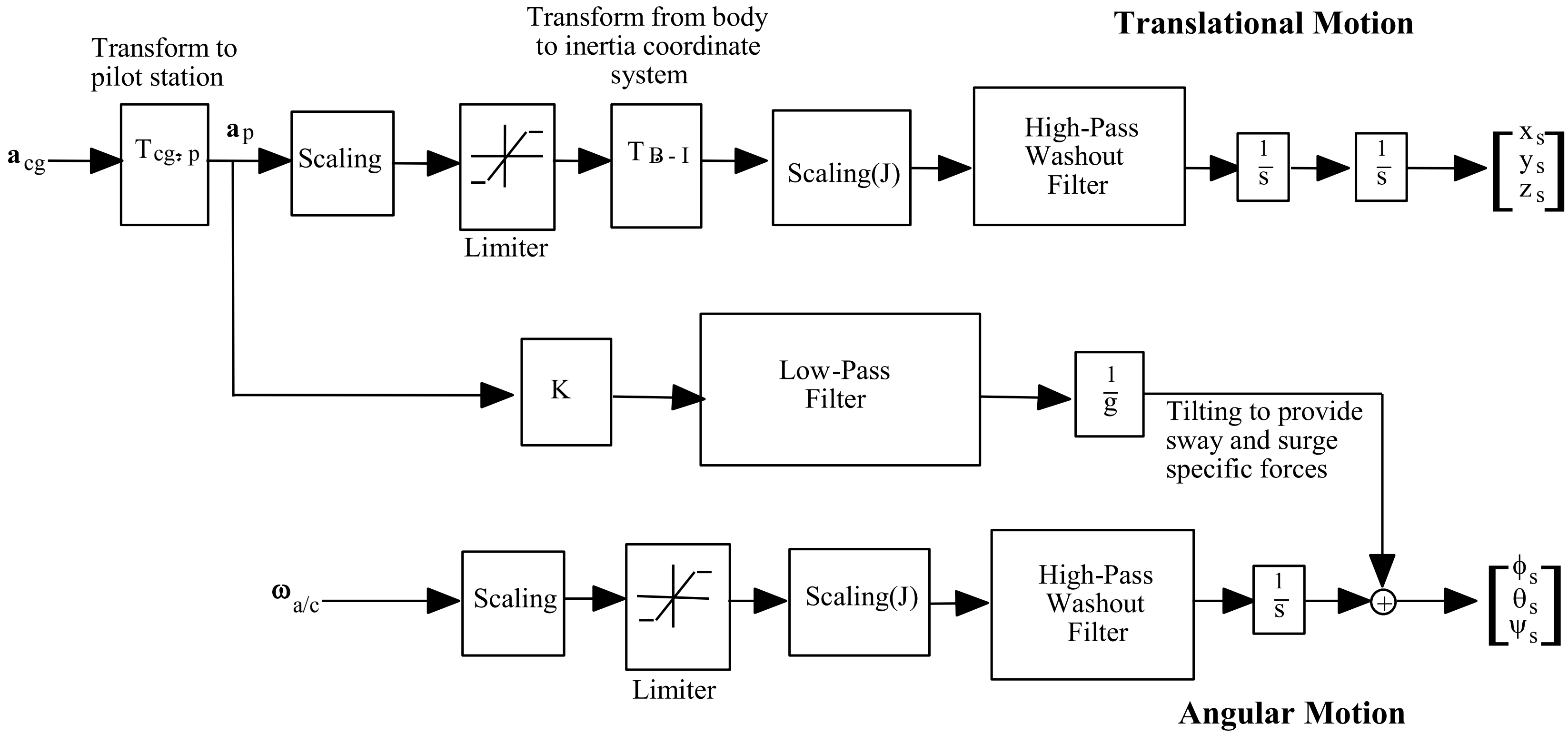


Figure 5-6. B747-400 Motion-Drive Algorithm

5.2.3.5 Motion tuning

The fidelity of the motion cues, i.e., how well the magnitude and the phase of the motion cues correspond to the airplane response, was critical to the purpose of this study. Therefore, one of the objectives of this effort was to maximize the travels of the B747-400 for the maneuvers selected for this study to achieve the maximum allowable motion-cueing fidelity.

For this purpose, the motion washout filters were adjusted according to the recommendations found in Sinacori (1977), Schroeder (1999), and Mikula, Chung, and Tran (1999). The goal was to maximize actuator travels for the maneuvers for this study, namely, V_2 and V_1 cut and PIA and SSL. Trade-offs were made to focus on the lateral side forces and heave motion cues, which are the critical motion cues perceived by pilots for these maneuvers, as explained by Bray (1972; see also experimental results described in Schroeder, 1999): "For large aircraft, due to size and to the basic nature of their maneuvering dynamics, the cockpit lateral acceleration cues appear to be much more important than the roll acceleration cues. There was the indication that this observation might be extended to the generalization that in each plane of motion the linear cues are much more valuable than the rotational cues."

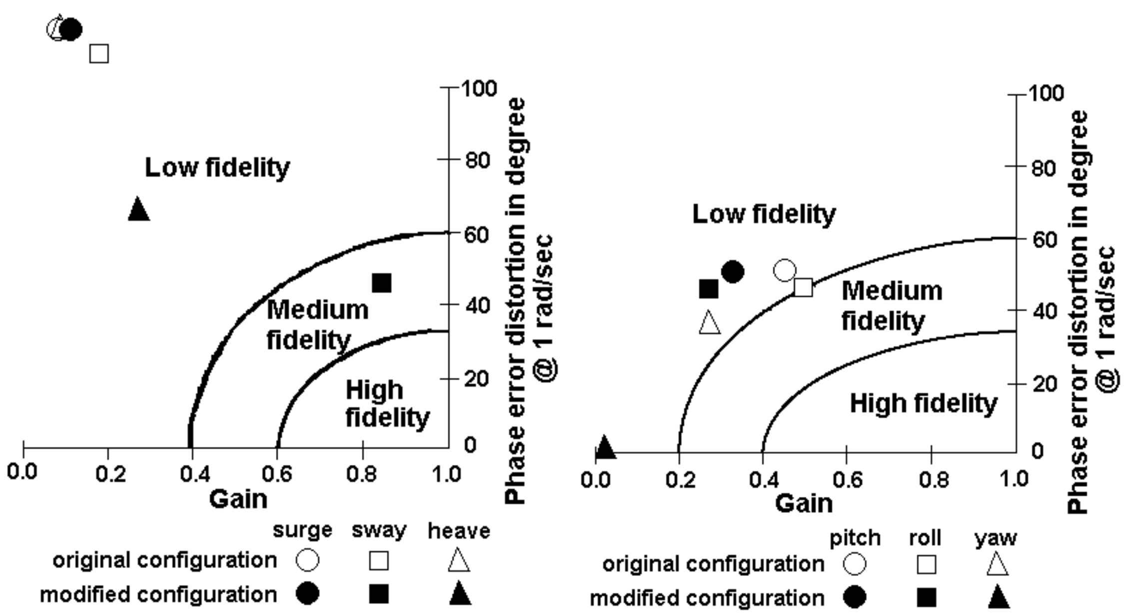


Figure 5-7. Before (empty symbols) and After (filled symbols) High-Pass-Filter Tuning

Before-and-after-tuning motion-cueing fidelity according to Sinacori (1977) and Schroeder (1999) are shown in Figure 5-7. In this figure, the respective gains are given along the x-axis, and the phase distortions on the y-axis. The original configuration is given as empty symbols, and the modified configuration as filled symbols.

The magnitude of the roll-motion cues was traded off to generate lateral side-force cues that would exceed the perceptual threshold of .005-0.01 g (Meiry, 1966; Zaichik, Rodchenko, Rufov, Yashin and White,1999). The reduced roll motion is especially justified given the lack of coordinated translational compensation in the motion-drive algorithm for the erroneous specific force induced by roll motion (Mikula et al., 1999).

The sway specific force, however, was provided by a combination of a high-pass washout filter for the onset cues, and a low-pass tilt for the sustained cues. The comparison between the original configuration and the modified one is shown in Figure 5-8 using a .5 Hz pulse (a pilot control-input frequency observed during V_1 cut and V_2 cut).

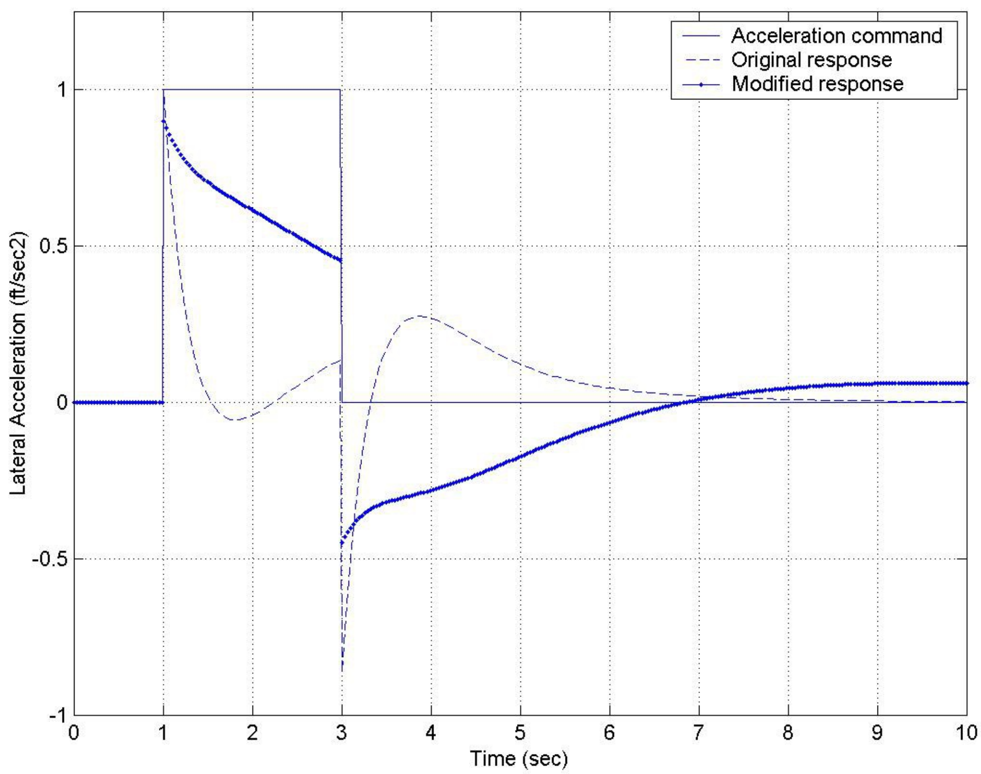


Figure 5-8. Comparison Of Lateral Side Force Before and After Tuning

In what was perhaps the largest tuning trade-off, yaw motion was eliminated for both ground and up-and-away flight conditions. This trade-off was based on Schroeder's 1999 finding that pilots perceive strong rotational lateral motion cues from translational lateral motion alone. By eliminating yaw motion, the translational motion cues in sway and heave were strengthened, which were deemed more important for the test maneuvers. This was true especially for the engine failures, which cause substantial side forces, and for the vertical upset. Only minor adjustments were made to the pitch and longitudinal motion axes.

5.2.3.6 Simulator calibration

All four FAA Level D certification quarterly checks for the B747-400 simulator were performed prior to the start of the experiment, thus covering the entire FAA Qualification Test Guide. Test results showed full compliance with FAA performance guidelines. The morning-readiness test provided by the simulator manufacturer, which checked visual, instruments, lights, control, sound, and motion, was run on a weekly basis. Functional checks of the simulator, which included control loading, motion, visual, Flight Management System, autopilot, and radio communication were performed manually every morning prior to the test. In addition, an automated approach and landing with full simulator systems was flown every morning to ensure the motion-system performance was consistent throughout the experiment. The time trace of this automated daily calibration check is shown in 2. The FAA inspected the B747-400 simulator in early March and the Level D certification was renewed on March 12, 2002.

5.2.4 Participants

5.2.4.1 Pilots Flying (PF)

Data were collected from 40 currently qualified Boeing 747-400 captains and first officers volunteering for the study. They were compensated for their expenses and time. Because the experiment was a between-subjects design, they were counterbalanced across the two motion conditions to avoid any spurious effects due to differences in the seat occupied during flying (captains left, first officers right), experience (low vs. high, the latter defined as more than 14 landings flown in the airplane in the past year), and Pilot-Not-Flying (PNF, one of two).

Total flight hours for the PFs in the experiment (20 Motion and 20 No-Motion) averaged 12,144. The average for the Motion group was 12,755 hours compared to 11,534 in the No-Motion group. The number of hours in the B747-400 airplane averaged 2,025 for the combined groups, with 2,260 hours for the Motion and 1,790 for the No-Motion group. The average number of landings in the past 12 months was 19 and 17 for the Motion and No-Motion groups, respectively.

Pilots were briefed orally and in writing that the overall purpose of the experiment was to improve simulator design for training and evaluation of airline pilots. They were informed that they would be flying challenging maneuvers to test different simulator configurations and specifically told to fly the flight director and/or guidance systems as precisely as possible. Also, they were informed that they would fly in the vicinity of a specific airport and were given airport, weather, and airplane information on the reverse side of the pilot briefing page (3). The latter information was briefed by the PNF just before starting the experiment. They were told that they would be given a chance to practice the maneuvers with graphical feedback on their flight-path precision and were shown generic feedback displays depicting the performance criteria. For the best performances, an award was promised. They were given complete responsibility and command of the airplane and told that the PNF would only follow commands.

They were also given a schedule of approximate flying, questionnaire, break and refreshment times. They were asked to hold any comments for the questionnaires.

Finally, they were asked to use discretion and not discuss the experiment with their colleagues, so that new participants would be fresh to the experiment.

5.2.4.2 Pilots Not Flying (PNF)

The PNFs were two retired airline pilots, one a former B747-200 Captain, the other a former B767 Captain. They were familiar with the purpose of the experiment, the simulator and the maneuver sequence flown, but they were not informed on the motion configuration. They were instructed to assist the pilot flying as requested in all non-flying duties, but not to initiate any actions.

5.2.4.3 Air Traffic Controller (ATC)

A retired air route traffic control center controller who was also responsible for running the simulator impersonated ATC. Instructions were kept as simple as possible. The script used by ATC can be found in 4.

5.2.5 Procedures

An experiment run could last up to seven hours including lunch, dependent on the smoothness of the runs and the time it took to complete the questionnaires. Pilots were asked to arrive at eight o'clock in the morning and started the day with refreshments and paperwork. They were assigned to the Motion or No-Motion group based on their experience and on the seat they were flying from. They were briefed on the experiment and shown sample performance-feedback displays to motivate them to fly as precisely as possible. The detailed experiment protocol can be found in 5.

During Evaluation, which tested the effect of motion on reverse-transfer of skills from the airplane to the simulator, and Quasi-Transfer Testing, which tested the effect of motion on transfer from the simulator to the simulator with motion as a stand-in for the airplane, the pilots flew two full scenarios consisting of a takeoff with an unrecoverable engine failure from DFW runway 36 Right followed by a loop around the airport to land on runway 36 Left or Right. After completion of the two scenarios, the PF and PNF returned to the briefing room and completed the first questionnaire. For the PF, this consisted mainly of an evaluation of the simulator. The PNF evaluated the PF (see 6 for all PF questionnaires and 7 for all PNF questionnaires).

During Training, pilots flew each maneuver three times in a row, with the opposite engine failed compared to Evaluation. The maneuver training sequence was counterbalanced across groups to control for sequence effects. Each pilot within a group experienced a different one of the 4!=24 possible sequences, and the same 20 sequences were used in each group. Pilots were told which maneuver to expect to enhance the effect of practice. Each training-maneuver run was followed by a display of the main performance variables specified in the PTS as a function of distance from the runway, with "perfect" flight precision given as a reference. After completion of Training, pilots returned to the briefing room to fill out another questionnaire.

During Quasi-Transfer Testing, pilots repeated the scenarios tested during Evaluation, now all with motion. The same engine was failed as during Evaluation. After having flown both scenarios, a third questionnaire was administered to both pilots in the briefing room. Then, the two scenarios were repeated one last time, followed by a final questionnaire. Pilots were thanked and encouraged to send their colleagues, without informing them about the details of the experiment. The experiment phases are outlined below.

Morning: Evaluation and Training with motion on or off dependent on group

Phase I: Evaluation

- Evaluate Scenario 1: V_2 cut (Engine 1) followed by PIA
- Evaluate Scenario 2: V_1 cut (Engine 4) followed by SSL

PF and PNF complete PF and PNF Questionnaire 1

Briefing on feedback displays using display copies printed during the last maneuver

Phase II: Training

- Train 3 V_2 cuts, PIAs, V_1 cuts, SSLs, failing the opposite engine
- Show feedback displays after each individual maneuver

PF and PNF complete Questionnaire 2

Lunch

Afternoon: Quasi-Transfer Testing with motion on for all

Phase III: Quasi-Transfer Testing

Test 1

- Quasi Transfer to motion Scenario 1
- Quasi Transfer to motion Scenario 2

PF and PNF complete Questionnaire 3

Test 2

- Quasi Transfer to motion Scenario 1
- Quasi Transfer to motion Scenario 2

PF and PNF complete PF Final Questionnaire and PNF Questionnaire 4

5.2.6 Performance Feedback Displays

After each training maneuver, pilots were shown, on the navigation display screen, the flight profile of the maneuver just performed in comparison with the ideal profile and the boundaries defined in the FAA PTS. The PTS performance criteria are described in 5.3.1.1. Pilots could take as much time as they needed to assess their performance and strategize on how to improve it.

5.2.6.1 Takeoff feedback displays

Takeoff performance feedback for the V_2 and the V_1 cuts was given as a function of distance from the runway on two pages displayed in sequence. The x-axis ranged from minus one to plus three nautical miles longitudinal distance from the runway threshold. The engine-failure location was marked with a red arrow. The first page showed heading deviation and airspeed deviation, the second page showed bank angle and altitude. Where applicable, the tolerances defined in the PTS were marked with a green line. The airplane's time trace was shown as a dotted line from start to reaching an altitude of 800 ft AGL. The dots were magenta as long as the airplane was within tolerances, and turned red once the tolerances were exceeded.

Page 1: Heading and airspeed deviation

Page 1 is shown in Figure 5-9. The heading deviation plot y-axis ranged from plus to minus 10 degrees deviation from takeoff heading. Two solid green lines indicated the range of desired performance of plus/minus 5 degrees.

The airspeed deviation plot y-axis ranged from plus to minus 10 knots deviation from the desired speed, which was V_2 + 10 knots for the V_2 cut and V_2 for the V_1 cut (160 and 150 knots, respectively). Two solid green lines indicated the range of desired performance of plus/minus 5 knots.

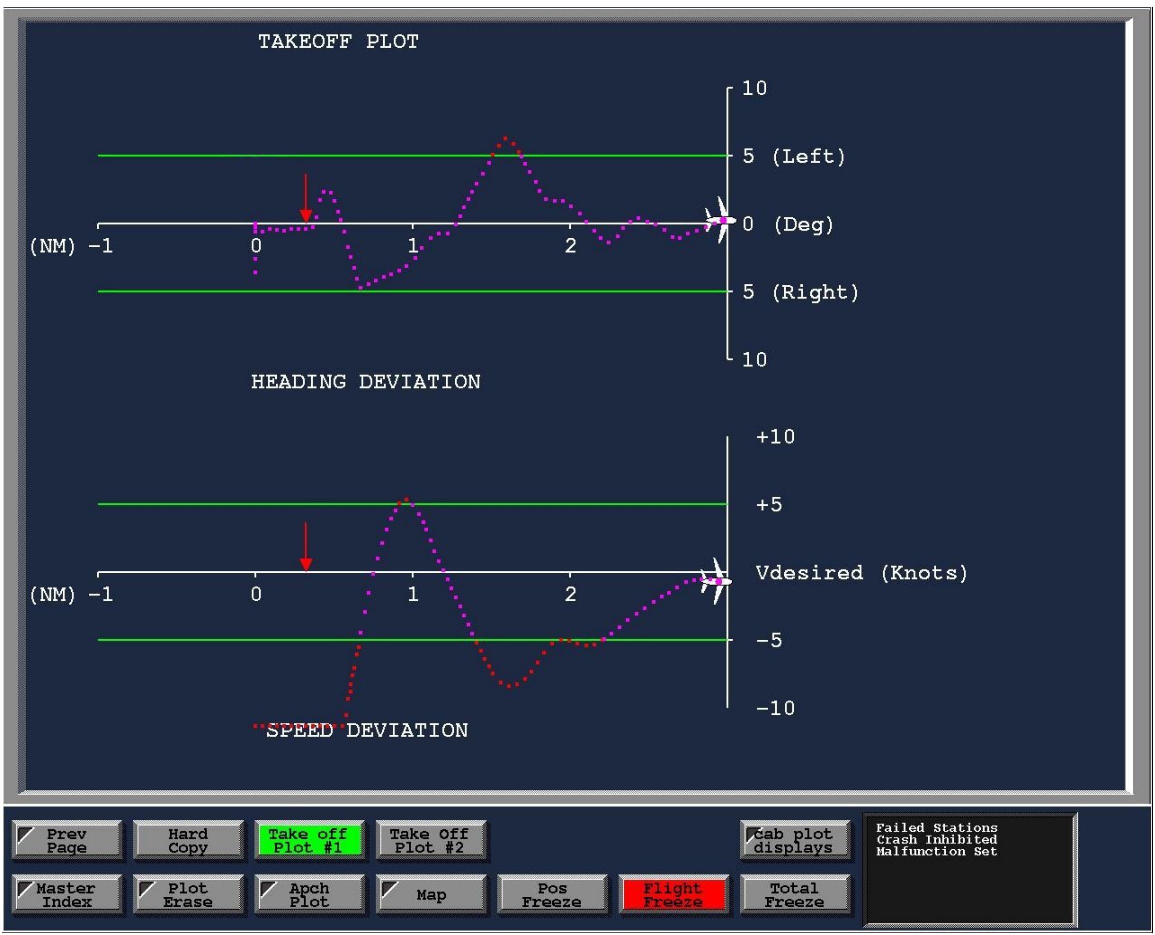


Figure 5-9. Feedback for Takeoff Heading and Speed

Page 2: Altitude and bank-angle plot
Page 2 is shown in Figure 5-10. The altitude profile y-axis ranged from zero to 1000 ft in 250 ft intervals. No PTS are available or given.

The bank-angle plot y-axis ranged from 10 degrees bank angle to the right to 10 degrees to the left, with the origin at zero degrees bank angle/3 nm from runway threshold. Plus/minus 5 degrees bank angle were given in dashed green as a reference (see 5.3.1.1 for the PTS for banking performance).

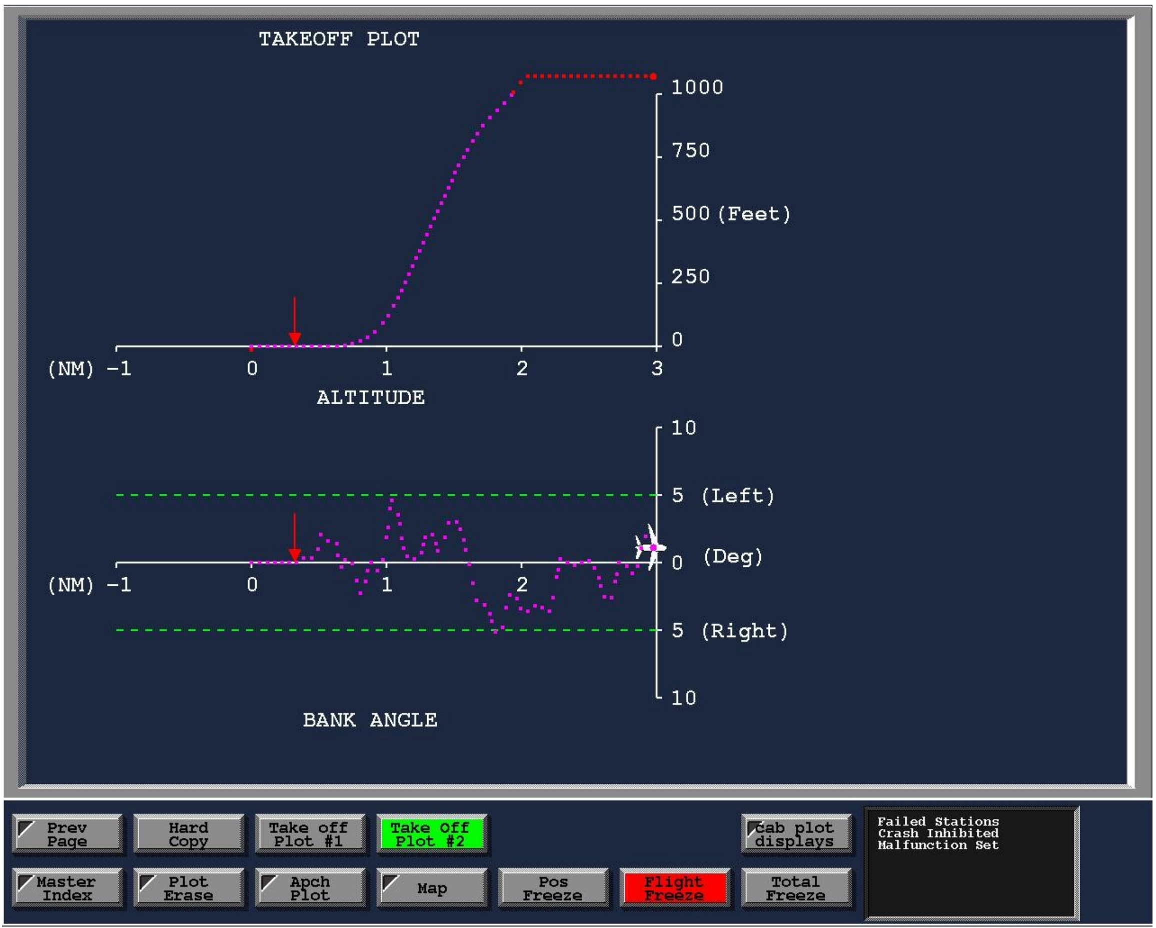


Figure 5-10. Feedback for Takeoff Altitude and Bank Angle

5.2.6.2 Approach and landing performance feedback displays

The approach and landing performance feedback for the PIA and SSL was given on one page, containing three plots showing glide path, localizer, and approach-speed deviation (see Figure 5-11). The x-axis again showed longitudinal distance from runway threshold, ranging from plus four to minus two nautical miles. A red arrow indicated the point of landing. The airplane performance was shown as a green dotted line when within PTS. Outside of PTS criteria, the dotted line turned red.

Glide-path and localizer deviations were shown as plus/minus one dot on the y-axis. Plus/minus one dot was also shown as the performance criterion (this time in white). For the glide path, the dots represented altitude, resulting in an altitude profile view. For the localizer, the dots represented horizontal distance from the runway centerline, resulting in a bird's eye view. The plus/minus one dot criterion is more lenient than the PTS criterion of plus/minus 0.5 dot, to compensate for the added difficulty of mandatory removal of the flight director during the maneuvers.

The speed deviation plot showed a range of plus/minus 20 knots deviation from the speed selected by the pilots on the Mode Control Panel on the y-axis. Compliance with the PTS was indicated by the dotted airplane performance curve turning red when the criterion of plus/minus 5 knots was violated.

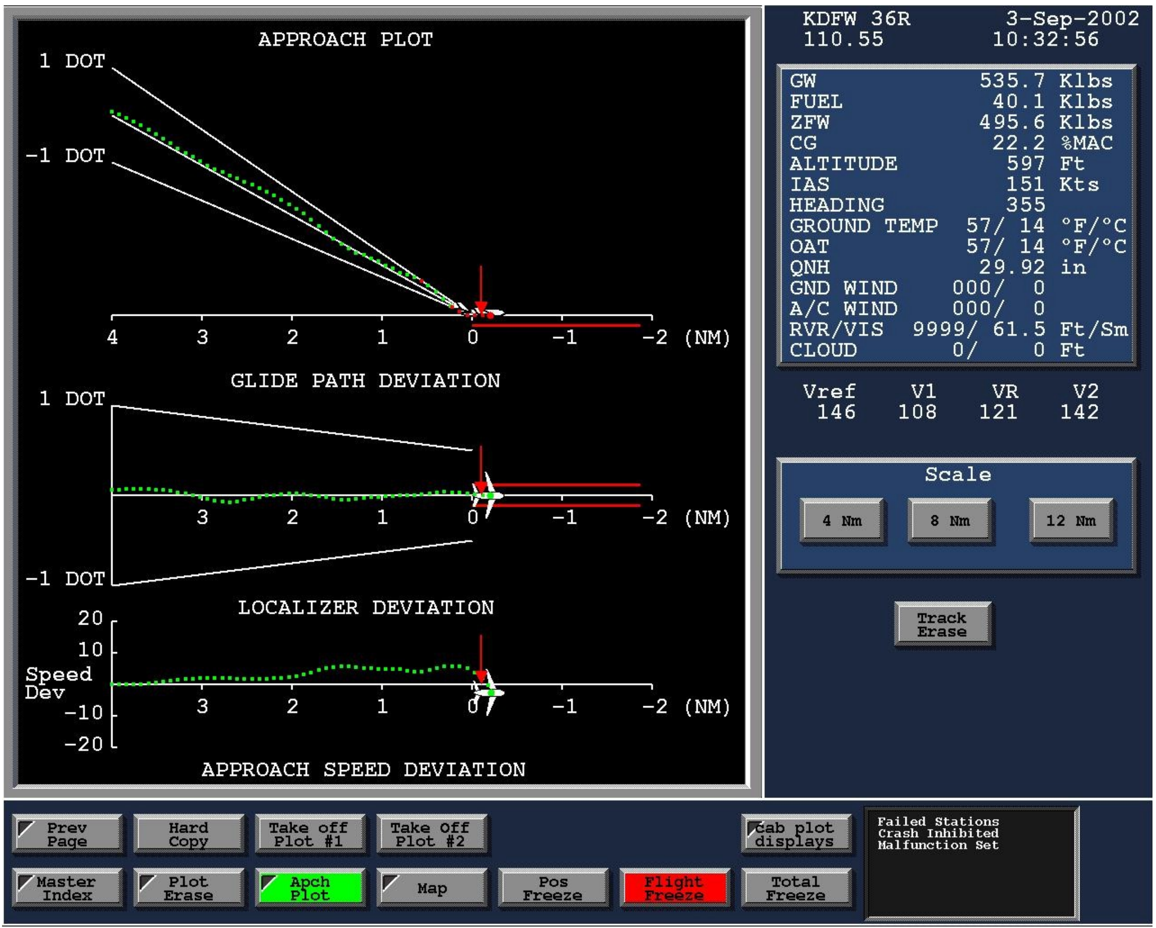


Figure 5-11. Feedback on Glide Path, Localizer, and Approach Speed Deviation

5.2.7 Data Collection

5.2.7.1 Simulator data

During each run of the experiment, variables that were considered useful for assessing the simulator performance, pilot performance, and pilot control activities, were recorded from the simulator computer at 30 Hz sampling rate. The list of the recorded variables is given in 8.

The statistics of some variables were also generated immediately after each run. These statistic data were saved in an Excel compatible text file. Note that the statistics calculations were done for each segment of a maneuver. The segments used in the maneuver analysis will be described in the 5.3.1.

5.2.7.2 Questionnaires

As described in 5.2.5, PFs and PNFs completed questionnaires immediately after each phase of the experiment, i.e., Evaluation, Training, and Quasi-Transfer Testing 1 and Quasi-Transfer Testing 2. Pilots were asked to relate the questionnaires only to the maneuvers flown or observed so far or since the last break.

PF questionnaires

The purpose of the PF questionnaires was to tap Boeing 747-400 pilots' expertise with regard to the Control Feel, Control Sensitivity, Handling Qualities, and overall Acceptability of the simulator. They were asked to assess their Control Strategy and Technique, Performance, and ease of Gaining Proficiency. They were also asked the Comfort and Workload experienced in the NASA simulator. As appropriate, PFs were asked compare these assessments to the airplane and in some cases to the last simulator flown. Finally, PFs were asked whether any "other" cues did not correspond to the airplane, without directly naming visual, auditory, or motion cues. Where appropriate, the questions were asked separately for each control and each maneuver. It was acknowledged that the PFs may not have experienced some of the maneuvers in the airplane, but they were asked to use their overall experience with the airplane to develop an expectation on how the airplane would have "behaved" during the maneuver. Most questions were asked on a scale from one to seven, with one anchored as "much worse," four "the same" and seven "much better" than the (aircraft). All PF questionnaires are reproduced in 6.

The questionnaires after the Evaluation (PFQ1) and Quasi-Transfer Training 1 (PFQ3) were identical, with the exception that PFQ3 had one additional page on Gaining Proficiency. The questionnaire after Training, PFQ2, was an abbreviated version of PFQ1, asking first for an overall rating and then for an indication as to which control or maneuver the judgment applies to. During analysis, the responses were translated into the same format as PFQ1. In general, responses consisted of checkmarks with the opportunity to add comments, with the exception of the final questionnaire, PFQfinal, which asked for open-ended responses to all aspects previously covered.

PNF questionnaires

PNFs were asked to rate the PFs' Control Performance, Control Strategy and Technique, Physical Workload and, in the questionnaire after training, ease of Gaining Proficiency. Specifically, they were asked, on a seven-point scale, whether, e.g., the PFs "performance" was "much worse (1)," "the same (4),"or "much better (7)" than the "performance" of the average pilot. When considering the results of the PNF questionnaires, the fact that PNFs in this study knew that the motion configuration of the simulator served as the main independent variable must be kept in mind. Although the motion status was concealed from both pilots, PNFs awareness of it for each particular experimental run may have been heightened through that knowledge, resulting in a potential for bias. PNFs were counterbalanced across motion conditions, taking into account PF experience and seat, to control for potential differences in bias between the PNFs. All PNF questionnaires are reproduced in 7.

5.3 Results Based On Simulator Recordings

5.3.1 Data Analysis

5.3.1.1 Performance standards

One critical question with regard to analyzing the results of the experiment is what performance criteria to apply. The following guidance for each maneuver was found in the FAA's Practical Test Standards (FAA, 2001).

Engine failures with continued takeoff
The PTS require that desired heading is maintained within plus/minus 5 degrees, and desired airspeed within plus/minus 5 knots. With regard to bank angle, it is recommended that a bank of approximately 5 degrees toward the operating engines is established, as appropriate for the airplane flown.

Engine-out approaches
In flight, the PTS for multiengine airplanes require that with an engine failure, positive airplane control and coordinated flight are maintained, with a bank angle of approximately 5 degrees, as required, and proper trim for that condition. Altitude, airspeed, and heading have to be within plus/minus 100 ft, 10 knots, and 10 degrees, respectively. Touchdown should be 500 to 3000 feet past the runway threshold, not to exceed one third of the runway length. The runway centerline has to be between the main gears.

For hand-flown PIAs and SSLs with an engine failure, a one-dot deflection from the localizer/glide slope indicators is tolerated. However, in the following analysis, localizer/glide slope exceedance calculations were based on half-dot (one-quarter scale) deflections from the on-localizer or on-glide slope position.

Engine-out landings
Again, a bank of approximately 5 degrees to maintain coordinated flight is permitted. Prior to beginning the final approach segment, pilots are to maintain the desired altitude, airspeed, and heading within plus/minus 100 ft, 10 knots, and 5 degrees. During the stabilized approach, desired airspeed/V-speed is to be maintained within plus/minus 5 knots.

5.3.2 Success Rates

Only data from successful trials were included in the analyses. A successful trial was defined as one without loss of control or abnormal ground contact (such as a wing or tail scrape). To be considered a success, takeoff maneuvers must also have been flown within four standard deviations (STD) of the mean maximum heading and bank deviation, while landing maneuvers must have been flown within four STDs of the mean maximum GS or LOC deviations found in the data. In calculating the success rate, missed approaches were excluded from the number of total maneuvers. As can be seen in Figure 5-12, the success rates of the two groups across maneuvers and phases were remarkably similar, with no significant Group differences (Fisher's Exact p>.5 for all maneuvers in all phases).

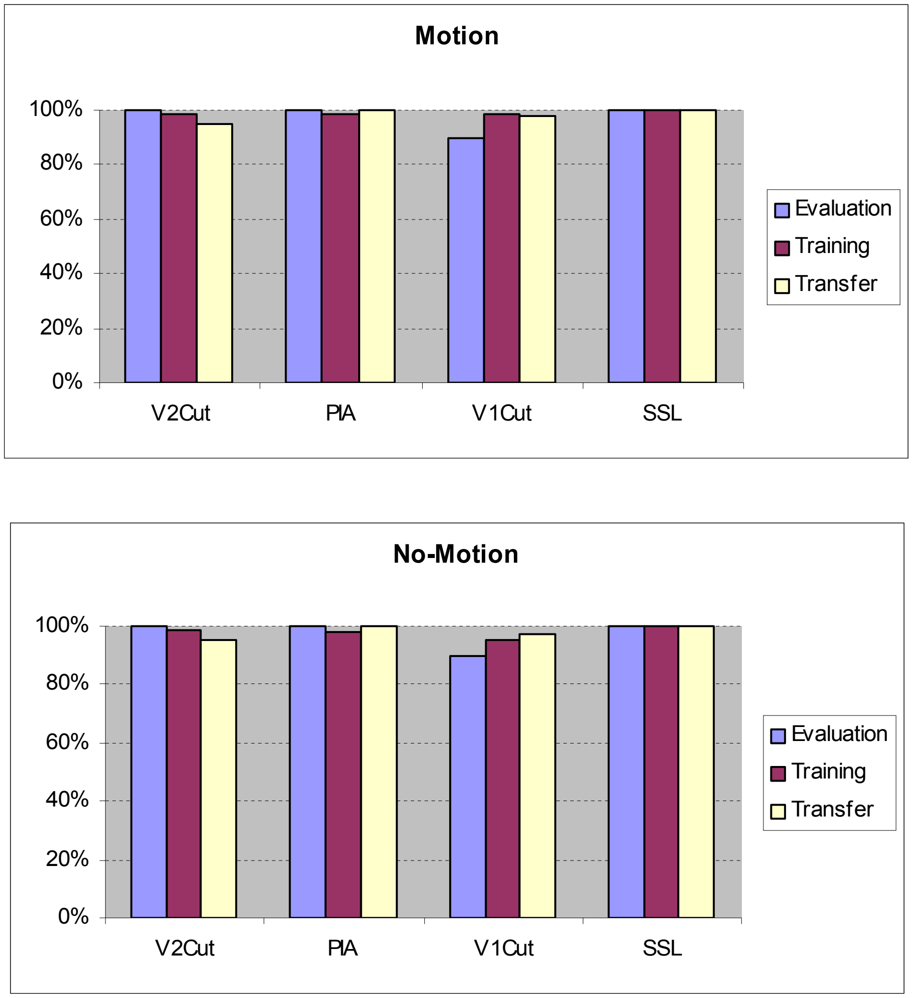


Figure 5-12. Success Rates by Phase and Maneuver

5.3.3 Performance and Behavior During Maneuvers

For the purpose of the data analyses, the maneuvers were divided into several flight segments. For each segment, a list of critical variables considered discriminative of pilot performance/behavior for the flying task of that particular flight segment was developed. The division of a maneuver into several flight segments was necessary because each segment requires a different set of variables to capture descriptive pilot flight-precision performance and behavior.

The segments used in the current analysis are as follows:

For engine failure on takeoff (V_1 cut and V_2 cut):

- After engine failure to 800 ft AGL

For Precision Instrument Approach:

- From final Approach-Fix to Decision-Height (1020 ft MSL)
- From Decision-Height to Touchdown

For sidestep landing:

- From final Approach-Fix to Breakout-of-Clouds (1688 ft MSL)
- From Breakout-of-Clouds to Upward-Gust (2 nm from runway threshold)
- From Upward-Gust to Touchdown

The list of measures calculated for each segment can be found in 9

5.3.3.1 Types of measures

Generally, the measures used in the analysis can be categorized into measures related to pilot-vehicle flight-precision performance (performance measures) and measures relating to pilot control actions (behavior measures). The list of measures for each maneuver and flight segment and their definitions are given in 9. Most of these measures were calculated from the time-history data recorded during the experiment. Some behavior measures, however, were derived from frequency domain analyses, specifically power spectrum analyses. This was necessary to capture pilot-response characteristics such as the frequency bandwidth of a pilot's control inputs, which is defined as the frequency below which half of the control-input power occurs. All the calculations were done using SAS™.

5.3.3.2 Data analysis procedure

Only data from successful trials were included in the analysis. The criteria for a successful trial can be found in the section on Success Rates (5.3.2). This led to the exclusion of less than 2.2 percent of trials in each group.

Given the physics of airplane motion and the characteristics of human pilot control, the performance and behavior measures discussed above are interrelated. Therefore, multivariate analysis of variance (MANOVA) was used to examine the effects of the independent variables of the experiment. The use of MANOVA instead of multiple univariate analyses of variance (ANOVA) was also intended to reduce the possibility of Type I error, i.e., a false *rejection* of the null hypothesis that motion has no effect. MANOVAs were performed on each flight segment separately. All the analyses included dependent variables to assess performance and behavior in all axes, which were derived from the measurements of heading deviation, bank angle, pitch angle, roll rate, yaw rate, airspeed deviation, wheel response, pedal response, and column response. In some cases, additional dependent variables were used as necessary, e.g. reaction time based on pedal response in takeoff maneuvers, and localizer and glide slope deviations in landing maneuvers. Although MANOVA is specifically designed to handle multiple correlated dependent variables, too many highly correlated dependent variables will result in a loss of degrees of freedom and power. This, in turn, will increase the probability of Type II errors, i.e., a false *acceptance* of the null hypothesis that motion has no effect. Hence, first a correlation analysis was performed to examine the interdependency of the measures. Only one representative from two or more highly correlated ($r>.85$) variables was then entered into MANOVA to preserve its power.

The main analysis involved a two-way MANOVA to examine the effect of the independent variables Group (Motion vs. No-Motion) by Phase (Evaluation, Training, Transfer) on the dependent variables. Interactions between Group and Phase were examined with two separate one-way MANOVAs on each group with Phase as the independent variable. A third set of MANOVAs examined the effect of Group and, where applicable, Trial separately for each phase, resulting in a one-way MANOVA for Evaluation and in two-way MANOVAs for Training (2 Groups by 3 Trials) and Transfer (2 Groups by 2 Trials). Because no effects of, or interactions with, Trial were found, no further analyses were warranted for the effect of the trial variable. Significant MANOVAs were followed up by univariate ANOVAs on the chosen variables. Differences between means were analyzed with Bonferroni t tests. All analyses were performed in SAS™.

Any difference with a probability to have occurred by chance of lower than 5 percent ($p<.05$) was considered a statistically significant effect (note that statistical significance is not necessarily synonymous with operational relevance). Probabilities of lower than 10 percent were considered a trend ($p<.10$). In Phase III, the data for Tests 1 and 2 were collapsed, because no statistically significant differences were found between them. Phase II was treated similarly, collapsing the data for all the successful training trials of each maneuver. Although results from all segments are presented, the emphasis will be on the results from the most critical flight segment of each maneuver.

It should also be mentioned that of the four statistics commonly used to evaluate the MANOVA results (Wilks' Lambda, Pillai's Trace, Hotelling-Lawley Trace, and Roy's Greatest Root), only Wilks' Lambda is reported. These four statistics did not yield exactly the same values, but they agreed with each other in terms of the level of significance or p-value.

The purpose of these analyses is to answer the following questions:

- Did the Motion and the No-Motion groups differ in flight-precision performance and/or control activities?
- Was there improvement across the different phases of the experiment?
- Did this improvement quasi-transfer to the simulator with motion as a stand-in for the airplane?
- Was there a difference in improvement and quasi transfer as a function of Group?

Successful quasi transfer was defined as having been achieved if any of the following results was found:

- Significant improvement between Phase I (Evaluation) and Phase III (Quasi-Transfer Testing), but no differences between Phase I and Phase II (Training) and Phase II and Phase III, indicating that there must have been some improvement between Evaluation and Training that did quasi-transfer, but that additional improvement during Quasi-Transfer Testing was needed to result in significant improvement from Evaluation

- Significant improvement between Phase I and Phase II, and I and III (Quasi-Transfer Testing), indicating that the improvement achieved during Training has quasi-transferred without additional improvement during Quasi-Transfer Testing.
- Significant improvement from Phase I to Phase II, and no differences between II and III and I and III, indicating that some, but not all of the improvement during Training has quasi-transferred
- Significant improvement between Phase I and II, and II and III, and thus also between I and III, indicating that the improvement during Training has quasi-transferred, and that additional improvement has been achieved during Quasi-Transfer Testing

5.3.3.3 Resolution (Power)

It is very important for consideration of experimental results to know whether the data gathered was consistent enough to reveal an operationally relevant effect (resolution of the study). The detectable effect size can be assessed using power analysis. The power of an experiment to reveal a relevant effect is directly proportional to the size of such effect and the number of subjects in each compared group, and indirectly proportional to the variability between subjects within each group. A finding of no difference between two groups does not necessarily mean that the difference is absent, but that the difference may be small enough to be masked by the variability of subjects within groups. For this study, the resolution of the analysis was inferred by calculating the required size of an effect to reach a power level of .80. That means that the effect size was defined as the minimum difference between the standardized means that will lead to the rejection of the null hypothesis with a probability of .80.

Maneuver	Measure	Effect Size	
		Group	**Phase**
V_2 Cut	STD bank	1.45 deg	1.72 deg
	STD HDG deviation	.75 deg	.89 deg
	Pedal RT	.43 s	.51 s
V_1 Cut	STD bank	.52 deg	.61 deg
	STD HDG deviation	.51 deg	.59 deg
	Pedal RT (s)	.18 s	.22 s
PIA	STD GS deviation	.07 dot	.08 dot
	STD LOC deviation	.14 dot	.17 dot
SSL	STD GS deviation	.07 dot	.08 dot
	STD LOC deviation)	.11 dot	.13 dot

Table 5-1. Detectable Group and Phase Effect

In this study, power analyses were done on the dependent variables that were related to the variables presented to pilots as feedback on their performance during the training phase. Only the data from the most important flight segments were considered, namely, the segment after engine failure during takeoffs and the segment before reaching decision height for PIA and before touchdown for SSL. Table 5-1 summarizes the group and phase effect sizes for the analyses done here.

These calculations show that the analyses could detect sufficiently small group or phase differences. Therefore, this study should serve the purpose of capturing the operationally relevant effects.

5.3.3.4 V_2 cut

For this maneuver, the dependent variables used in the MANOVA are as follows (15 variables):

Performance

- STD and average failure-induced heading deviation (average of heading deviation in the direction of the failed engine)
- STD bank angle
- STD pitch angle
- Average airspeed exceedance (average of airspeed exceeding the plus/minus 5 knots about the desired airspeed)

Behavior

- Pedal reaction time
- Root mean square (RMS) and number of reversals of column, wheel, and pedal responses
- Response bandwidth of the column, wheel, and pedal actions (frequency below which the corresponding power spectral density curves are .5 of total area)

The V_2 cut was affected by Group and Phase. This means that pilots performed and behaved differently dependent on whether they received or didn't receive motion cues or whether they had been trained with or without motion cues. It also means that they were affected by the Phase of the experiment they were in, i.e., whether they had just come fresh from the airplane and were evaluated in the simulator, were being trained in the simulator knowing which maneuver was to come and were provided with feedback, or had quasi-transferred to the simulator with motion on for all for final testing. However, the Group and Phase variables also significantly interacted with each other, which means that Group effects were depended on the Phase and vice versa. The overall statistics for the V_2 cut are, Wilks' Lambda $\Lambda=.66$, $F(15,99)=3.35$ (Group) and $\Lambda=.31$, $F(30,198)=5.23$ (Phase), both $p<.0001$; interaction $\Lambda=.65$, $F(30,198)=1.59$, $p<.05$.

The effect of Group on three of the 15 variables interacted with Phase ($F(2, 113)\geq3.88$, $p<.05$). Table 5-2 shows the Group effects for each phase. The Motion-trained group activated the pedal 0.76 s slower in response to the engine failure than the No-Motion group, but this effect emerged only at Quasi Transfer, when both groups received motion cues. Also only during Quasi-Transfer Testing, the Motion group had a 0.28 inch (in) higher column RMS than the No-Motion group. Finally, the Motion group reversed the pedal 0.45 times more often than the No-Motion group during Evaluation, but this effect disappeared during Training and did not re-emerge at Quasi Transfer.

Variable	Phase	Mean		Stats	
		Motion	No-motion	F	p
Pedal-reaction time (s)	I	3.40	3.77	(1,38)=1.81	.19
	II	2.49	2.30	(1,111)=1.16	.28
	III	3.10	2.34	(1,71)=8.69	.004
Pedal reversals	I	1.50	1.05	(1,38)=9.68	.004
	II	1.29	1.31	(1,111)=.04	.83
	III	1.49	1.61	(1,71)=.75	.39
RMS column (in)	I	1.17	1.23	(1,38)=.40	.53
	II	.99	1.03	(1,111)=.49	.48
	III	1.14	.86	(1,71)=10.22	.002

Table 5-2. V_2 Cut Group Effects by Phase (shading indicates significant group difference)

Table 5-3 shows the effects of Phase for each group. Both groups lowered their pedal-reaction time during Training. However, this improvement quasi-transferred for the No-Motion group only. Also only the No-Motion group increased its pedal activity (more pedal reversals) and lowered its column activity (lower RMS column) between Evaluation and Quasi-Transfer Testing.

Variable	Group	Differences			Stats	
		I-II	II-III	I-III	F	p
Pedal-reaction time (s)	Motion	.90*	-.60	.30	(2,56)=6.49	.003
	No-Motion	1.47*	-.13	1.34*	(2,57)=18.27	<.0001
Pedal reversals	Motion	.22	-.24	-.03	(2,56)=1.41	.25
	No-Motion	-.26	-.29	-.55*	(2,57)=8.10	.0008
RMS column (in)	Motion	.18	-.14	.04	(2,56)=1.76	.18
	No-Motion	.21	.17	.37*	(2,57)=9.67	.0002

* indicates significant difference (p<.05)

Table 5-3. V_2 Cut Phase Effects by Group

Group, regardless of Phase, affected three control related variables (Table 5-4). The Motion group demonstrated higher wheel activity (RMS, reversals) and lower pedal-response bandwidth.

Seven variables were affected by Phase regardless of Group (Table 5-5). Heading STD and average failure-induced heading deviation improved during Training, but the improvement did not quasi-transfer. This was true also for bank STD and wheel RMS. A pedal RMS decrease during Training quasi-transferred, but some of the improvement was lost. The increased wheel and pedal-response bandwidths found during Training compared to Evaluation were exhibited during Quasi-Transfer Testing for pedal only.

Variable	Mean		Stats	
	Motion	No-motion	F(1,113)	p
Wheel reversals	3.27	2.53	14.46	.0002
RMS wheel (deg)	6.97	5.44	16.05	.0001
Pedal-response BW (Hz)	.04	.05	4.84	.03

Table 5-4. V_2 Cut Group Differences

Variable	Mean	Differences			Stats	
		I-II	II-III	I-III	F(2,113)	p
STD HDG (deg)	3.66	.85*	-.96*	-.11	5.29	.01
Failure-induced HDG (deg)	5.47	5.40*	-4.03*	1.37	23.92	<.0001
STD bank (deg)	5.69	1.54*	-1.71*	-.16	4.54	.01
RMS wheel (deg)	6.20	1.22*	-1.15*	.07	4.38	.01
Wheel response BW (Hz)	.063	-.02 *	.01	-.01	3.16	.05
RMS pedal (in)	1.07	.19*	-.11	.08	7.61	.0008
Pedal-response BW (Hz)	.04	-.02*	.001	-.02*	10.63	<.0001

* indicates significant difference (p<.05)

Table 5-5. V_2 Cut Results for Phase (I=Evaluation, II=Training, III=Quasi-Transfer Testing)

Summary

Motion did not appear to alert of the engine malfunction for the V_2 cut. On the contrary, the Motion group slowed down its pedal response compared to the No-Motion group at Quasi Transfer, losing two-thirds of the improvement it had gained during Training, possibly due to fatigue. Only the No-Motion group, which may have been refreshed by the emergence of motion (the so-called Hawthorne effect, Homans, 1958), fully quasi-transferred the pedal-reaction time improvement achieved during Training. Nevertheless, there were only behavioral differences between the two groups, performance doesn't appear to have been affected by the presence or absence of Motion during any of the phases.

Of seven (counting also an increase in pedal-response bandwidth) variables that had significantly improved between Evaluation and Training regardless of Group, four significantly deteriorated during Quasi-Transfer Testing compared to Training. This may be another indication of fatigue.

During Evaluation only, the Motion group had more pedal reversals. This difference was lost across the experiment because the No-Motion group significantly increased its reversals between Evaluation and Quasi-Transfer Testing. The Motion group generally had a lower pedal-response bandwidth. Wheel activity was generally higher for the Motion group regardless of Phase. Unlike the Motion group, the No-Motion reduced its column activity between Evaluation and Quasi-Transfer Testing.

5.3.3.5 V_1 Cut

In addition to the dependent variables used in the V_2 cut analysis, four more variables are used in the MANOVA for the V_1 cut maneuver (resulting in a total of 19 dependent variables):

Additional performance variables

- Average heading exceedance (average of the heading deviation exceeding ± 5° around the desired heading direction)
- Average failure induced bank angle (average of bank angle in the direction of the failed engine)

Additional behavior variables

- Roll and yaw activities (average of absolute roll and yaw rates)

The overall effects of Group and Phase were again significant (Wilks' Lambda Λ=.47, F(19,92)=5.47 (Group) and Λ=.41, F(38,184)=2.74 (Phase), both p<.0001), and, just as for the V_2 cut, interacted significantly with each other (Λ=.56, F(38,184)=1.63, p=.02). This showed that for some of the dependent variables, the effects of one independent variable depended on the level of the other independent variable.

For five of the 19 dependent variables, Phase and Group interacted with each other (F(2,110)≥4.13, p<.05), and for one (STD heading), there was a trend of interaction (F(2,110)=2.59, p<.10). Table 5-6 shows the effects of Group for each phase. The Motion group responded 0.4 s and 0.3 s faster to the engine failure than the No-Motion group during Evaluation and Training, respectively. This difference disappeared when all pilots quasi-transferred to motion. It may be this decrease in pedal-reaction time that allowed the Motion group to apply lower pedal RMS and higher pedal-response bandwidth than the No-Motion group before quasi-transferring to all motion. Some other Group effects that appeared during Evaluation only were lower yaw activity, lower pitch STD, and lower heading STD for the Motion group (although this latter finding is weakened by the fact that for heading STD, there was only a trend of an interaction between Phase and Group, which renders the follow-up Bonferroni tests questionable).

Variable	Phase	Mean		Stats	
		Motion	No-motion	F	p
Pedal-reaction time (s)	I	1.53	1.92	(1,34)=5.02	.03
	II	1.40	1.68	(1,110)=14.72	.0002
	III	1.46	1.42	(1,74)=2.18	.14
STD heading (deg)	I	2.28	3.04	(1,34)=4.34	.04
	II	2.41	2.59	(1,110)=.97	.33
	III	2.14	1.93	(1,74)=1.16	.28
Yaw activity (deg/s)	I	.55	.79	(1,34)=7.26	.01
	II	.60	.66	(1,110)=2.17	.14
	III	.56	.50	(1,74)=1.59	.21
STD pitch (deg)	I	5.63	6.40	(1,34)=7.21	.01
	II	6.43	6.44	(1,110)=.00	.96
	III	6.39	6.12	(1,74)=3.73	.06
RMS pedal (in)	I	.62	.77	(1,34)=21.53	<.0001
	II	.60	.70	(1,110)=51.64	<.0001
	III	.61	.61	(1,74)=.05	.83
Pedal-response BW (Hz)	I	.11	.08	(1,34)=9.42	.004
	II	.11	.09	(1,110)=17.58	<.0001
	III	.12	.12	(1,74)=.38	.54

Table 5-6. V_1 Cut Group Effects by Phase (shading indicates significant group difference)

Phase effects for each group are shown in Table 5-7. The Motion group lowered its pedal-reaction time during Training, but this effect did not quasi-transfer completely. At the same time, the Motion group had increased pitch STD during Training and this effect fully quasi-transferred. The No-Motion group did not lower its pedal-reaction time during Training, but lowered it significantly during Quasi-Transfer Testing in the simulator with motion. With lower pedal-reaction time at Quasi Transfer, the No-Motion group also improved heading and yaw control (reducing STD heading and yaw activity), lowered pedal RMS, and increased pedal-response bandwidth compared to the earlier phases.

Variable	Group	Differences			Stats	
		I-II	II-III	I-III	F(2,55)	p
Pedal-reaction time (s)	Motion	.13*	-.06	.07	4.81	.01
	No-Motion	.22	.29	.50*	5.68	.006
STD heading (deg)	Motion	-.20	.30	.09	.46	.63
	No-Motion	.45	.60	1.04*	6.82	.002
Yaw activity (deg/s)	Motion	-.07	.06	-.01	.51	.60
	No-Motion	.12	.16	.28*	8.73	.0005

Variable	Group	Differences			Stats	
		I-II	II-III	I-III	F(2,55)	p
STD pitch (deg)	Motion	-.81*	.05	-.76*	8.95	.0004
	No-Motion	-.01	.34	.33	1.54	.22
RMS pedal (in)	Motion	.02	-.01	.01	.48	.62
	No-Motion	.07*	.10*	.17*	24.44	<.0001
Pedal-response BW (Hz)	Motion	.002	-.0005	.002	.01	.99
	No-Motion	-.006	-.03*	-.04*	16.57	<.0001

* indicates significant difference (p<.05)

Table 5-7. V_1 Cut Phase Effects by Group

Three variables showed Group differences regardless of Phase (Table 5-8). The Motion group used the wheel more aggressively (more reversals, higher RMS), but had fewer pedal reversals throughout.

Variable	Mean		Stats	
	Motion	No-motion	F(1,110)	p
Wheel reversals	5.72	4.49	11.74	.0009
RMS wheel (deg)	3.99	3.41	5.68	.02
Pedal reversals	1.16	1.45	11.60	.0009

Table 5-8. V_1 Cut Group Differences

Two roll variables improved across Phase regardless of Group (Table 5-9). Failure-induced bank increased during Training, but decreased at Quasi Transfer. Roll activity decreased at Quasi Transfer.

Variable	Mean	Differences			Stats	
		I-II	II-III	I-III	F(2,110)	p
Failure-induced bank (deg)	1.20	-.44*	.54*	.10	9.55	.0001
Roll activity (deg/s)	1.36	.11	.10	.20*	3.14	.05

* indicates significant difference (p<.05)

Table 5-9. V_1 Cut Results for Phase (I=Evaluation, II=Training, III=Quasi-Transfer Testing)

Summary

Pilots did use the motion cues to speed up their pedal-response time to the V_1 cut, for which a timely response is critical to prevent scraping the tail or a wing. However, although the No-Motion pilots were unable to significantly improve their response time even when they were told that an engine and even which engine would fail during Training, they immediately did use the motion cues to speed up their pedal response once available during Quasi-Transfer Testing. As might be expected, the faster pedal-reaction time of the Motion group compared to the No-Motion group during Evaluation and Training had beneficial effects on the Motion group's control performance and behavior.

Like for the V_2 cuts, the Motion group was generally more active with regard to the aileron wheel. Unlike for the V_2 cut, however, the Motion group had fewer pedal reversals, even at Evaluation. Unlike for the V_2 cut as well, motion seemed to induce higher pedal-response bandwidth for the Motion group, and for the No-Motion group when motion cues were made available during Quasi-Transfer Testing. General improvement regardless of Group was limited to roll variables.

Comparison with First Study

As described in 1, the same dependent variables as in the Second Study were analyzed for the V_1 cut of the First Study, except that average heading exceedance was omitted as it was heavily correlated ($r>.85$) with the other two heading variables. As in the Second Study, there was a significant overall Phase effect, but the overall Group effect was only marginal and there was no interaction between the overall Group and Phase effects. Table A1-3 shows that regardless of Group, general improvement was observed on bank and pitch performance as well as reduction in lateral-directional control activities at Quasi Transfer. For the Second Study, improvement was limited to roll variables.

Table A1-2 shows the results of further examining the Group effect—however the fact that the overall MANOVA for Group was only marginally significant needs to be kept in mind when considering these results. Throughout all phases, i.e., even during Quasi Transfer to the simulator with motion, the No-Motion pilots reversed the aileron wheel slightly more often, but with a lower bandwidth, than the Motion pilots. In contrast, they reversed the pedal slightly less frequently than the Motion pilots. There was no difference in how fast they activated the pedal (or the wheel)[3] after engine failure. This shows that the motion cues in the First Study only affected (albeit only marginally) pilots' lateral-directional control activities. Interestingly, although differences between groups on wheel and pedal reversals were also found in the Second Study, the pattern was opposite: the Motion group had fewer pedal reversals and more wheel reversals than the No-Motion group. Potential explanations for these differences are the dynamics of the simulated airplane and the difference in simulator motion performance.

5.3.3.6 Precision Instrument Approach

Approach-Fix to Decision-Height

The Approach-Fix to Decision-Height (Fix-to-DH) flight segment was considered the most important for the Precision-Instrument-Approach maneuver, because in this

[3] Although wheel reaction time was not included in these analyses, earlier analyses had not found any differences in wheel reaction times between the two groups for Evaluation ($F(1,35)=1.45$, $p=.237$) or Quasi-Transfer Testing ($F(1,32)=.07$, $p=.803$) (see Bürki-Cohen et al., 2001).

segment the pilots had to track glide slope and localizer closely with disturbances from shifting cross winds. The MANOVA for this segment used 17 dependent variables as follows:

Performance

- STD heading deviation
- STD bank angle
- STD pitch angle
- Average airspeed exceedance
- STD and average exceedance of glide slope and localizer deviations (average of integral of deviations exceeding plus/minus .5 dot)

Behavior

- RMS and number of reversals of column, wheel, and pedal responses
- Column, wheel, and pedal-response bandwidths

For the Fix-to-DH segment, both overall Group and Phase effects were significant (Wilks' Lambda Λ=.71, F(17,88)=2.10 and Λ=.57, F(34,176)=1.68, respectively, both p<.05). There was no interaction between Phase and Group [Λ=.77, F(34,176)<1; p>.10]. This means that any Group effects for the Precision Instrument Approach Fix-to-DH occurred during all three phases, and that any Phase effects occurred for both groups. Most importantly, this means that any effects found due to the motion condition persisted even when the No-Motion group quasi-transferred to motion.

The Group variable significantly affected seven of the 17 dependent variables examined. Table 5-10 presents these results collapsed over phases, because the analysis showed that these results were present during all phases, including Quasi-Transfer Testing when both groups flew with motion. The No-Motion group flew more precisely than the Motion group, with lower STDs around the desired heading and localizer, and lower bank STD. The No-Motion group seemed to achieve this performance with wheel-control inputs of lower magnitude, i.e., lower root mean square (RMS) and fewer reversals (number of times the wheel exceeds a ten-degree band around the neutral position). It used higher pedal-response bandwidth (which is the frequency below which the area under the pedal power spectral density curve constitutes half of the total area) than the Motion group.

Variable	**Mean**		**Stats**	
	Motion	**No-motion**	**F(1,104)**	**p**
STD heading (deg)	3.77	2.84	11.96	.0008
STD bank (deg)	3.35	2.92	5.61	.02
STD localizer deviation (dot)	.55	.36	14.39	.0003
Localizer exceedance (dot)	.25	.09	16.98	<.0001
Wheel reversals	8.93	6.68	6.00	.02
RMS	2.39	2.08	8.44	.005

Variable	Mean		Stats	
	Motion	No-motion	F(1,104)	p
Wheel (deg)				
Pedal-response BW (Hz)	.015	.025	6.68	.01

Table 5-10. Precision Instrument Approach Fix-to-DH Results for Group

Table 5-11 shows the dependent variables that were significantly affected by Phase. Both groups improved flight-precision performance (heading, bank, pitch, and localizer STD) and reduced control inputs (wheel and column reversals, RMS, and bandwidths) progressively with Phase, indicating that both simulator configurations resulted in effective training.

Variable	Mean	Differences			Stats	
		I-II	II-III	I-III	F(2,104)	p
STD heading (deg)	3.32	1.27*	-.15	1.13*	7.90	.0006
STD bank (deg)	3.15	.66*	-.25	.41	4.19	.02
STD pitch (deg)	1.21	.28*	-.004	.27*	3.92	.02
STD localizer deviation (dot)	.46	.21*	.004	.21*	6.36	.003
Wheel reversals	7.84	2.61	.94	3.55*	5.02	.008
Column reversals	4.57	2.03	1.20	3.22*	3.65	.03
RMS wheel (deg)	2.24	.46*	-.04	.42*	7.18	.001
Wheel BW (Hz)	.12	-.004	.03*	.02	3.86	.02
RMS column (in)	.51	.10*	.03	.13*	5.93	.004
Column BW (Hz)	.093	-.01	.03*	.02	3.59	.03

* indicates significant difference (p<.05)

Table 5-11. Precision Instrument Approach Fix-to-DH Results for Phase (I=Evaluation, II=Training, III=Quasi-Transfer Testing)

Decision-Height to Touch-Down

For the Decision-Height to Touchdown (DH-to-TD) flight segment, which is the shorter of the two segments and occurred with the runway in sight, 19 dependent variables are used in the MANOVA. The same variables as in the Fix-to-DH segment were used here with the addition of two performance variables, namely:

- Touchdown descent rate (the vertical speed of the airplane at touchdown)
- Touchdown distance (distance from the runway threshold at touchdown)

Group and Phase again significantly affected the results (Wilks' Lambda Λ=.63, F(19,86)=2.70 and Λ=.42, F(38,172)=2.43, respectively, both p<.001) without interacting (Λ=.66, F(38,172)=1.06, p>.10). As in the previous segment, the Motion group showed higher wheel activity, lower pedal response bandwidth, and a tendency for worse directional control than the No-Motion group (Table 5-12). In addition, the Motion group controlled airspeed worse than the No-Motion group and had lower column-response bandwidth. As in the previous segment, both groups were successfully trained, showing progressive improvement in flight precision (heading, bank, pitch, and localizer tracking) and reduction in control activities (wheel and column) with Phase (Table 5-13).

Variable	Mean		Stats	
	Motion	No-motion	F(1,104)	p
STD heading (deg)	2.95	2.38	3.55	.06
Average airspeed exceedance (kts)	5.07	3.55	4.55	.04
RMS wheel (deg)	3.81	3.20	7.54	.007
Column response BW (Hz)	.08	.11	13.80	.0003
Pedal response BW (Hz)	.05	.09	10.98	.001

Table 5-12. Precision Instrument Approach DH-to-TD Results for Group

Variable	Mean	Differences			Stats	
		I-II	II-III	I-III	F(2,104)	p
STD heading (deg)	2.68	1.15*	-.19	.96*	5.80	.004
STD bank (deg)	3.78	1.05*	-.45	.60	3.46	.04
STD pitch (deg)	1.24	.24*	-.12	.12	4.18	.02
Average glide slope exceedance (dot)	.29	.09	.01	.10*	4.43	.01
Wheel reversals	5.85	1.56*	.46	2.02*	8.13	.0005
Column reversals	5.45	2.13*	.89	3.02*	8.09	.0005
RMS	3.52	.71*	.21	.92*	6.41	.002

Variable	Mean	Differences			Stats	
		I-II	II-III	I-III	F(2,104)	p
wheel (deg)						
Wheel response BW (Hz)	.14	.01	.03*	.04*	6.29	.003
RMS column (in)	1.26	.14*	-.0003	.14*	4.84	.01
Column response BW (Hz)	.09	.02	.05*	.07*	15.00	<.0001

* indicates significant difference (p<.05)

Table 5-13. Precision Instrument Approach DH-to-TD Results for Phase (I=Evaluation, II=Training, III=Quasi-Transfer Testing)

Summary

Two separate segments of the PIA were analyzed, the approach Fix-to-Decision-Height segment and the Decision-Height-to-Touchdown segment. For neither of the segments was there an interaction between Group and Phase effects, so, whatever differences existed between the two groups, they persisted even when the No-Motion group quasi-transferred to motion. Both groups significantly improved on many variables across phases.

For both segments, the Motion group controlled the ailerons more actively than the No-Motion group, as it had also done for the takeoff maneuvers. But this increase in control activity did not lead to better lateral-directional control, on the contrary, the flight precision of the Motion group was inferior to the No-Motion group during all phases.

Also for both segments, the Motion group had a lower pedal-response bandwidth than the No-Motion group, as it had had for the V_2 cut but not the V_1 cut. Only for the DH-to-TD segment the No-Motion pilots had higher column-response bandwidth and better speed control.

5.3.3.7 Sidestep landing

Approach-Fix to Breakout-of-Clouds

The dependent variables used in the MANOVA for the Approach-Fix to Breakout-of-Clouds (Fix-to-BC) segment are as follows (a total of 20 variables):

Performance

- Maximum, STD, and average exceedance of heading deviation (average of heading deviations exceeding ±5° from the desired heading)
- STD and average exceedance of bank angle (average of bank angle exceeding ±5° from level attitude)

- STD pitch angle
- Average airspeed exceedance
- STD and average exceedance of glide slope and localizer deviations

Behavior

- RMS and number of reversals of column, wheel, and pedal responses
- Column, wheel, and pedal response bandwidths

Except for the constant 10-knots quartering headwind instead of the shifting crosswinds, the Fix-to-BC flight segment was similar to the Precision Instrument Approach from Fix to DH and thus yielded similar effects. The MANOVA results showed significant Group and Phase effects (Wilks' Lambda $\Lambda=.66$, $F(20,95)=2.43$, $p=.002$, and $\Lambda=.39$, $F(40,190)=2.87$, $p<.0001$, respectively), without interaction ($\Lambda=.62$, $F(40,190)=1.30$, $p>.10$). The similarity of the Group effects found in this segment to the Precision Instrument Approach Fix-to-DH segment can be seen in Table 5-14. The No-Motion group performed better compared to the Motion group with regard to directional control (heading and localizer tracking), and with lower wheel control activity. However, the significantly lower bank-angle STD and higher pedal bandwidth found for the No-Motion group with the Precision Instrument Approach were not found here, suggesting that these effects were related to the shifting winds. The effects of Phase were also similar to those found for the Precision Instrument Approach (Table 5-15). Both groups benefited from Training with better directional performance, lower column activity, and lower wheel-response bandwidth, and these benefits quasi-transferred.

Variable	Mean		Stats	
	Motion	No-motion	F(1,114)	p
Max heading deviation (deg)	6.53	5.66	4.14	.04
STD heading (deg)	2.58	2.04	4.81	.03
STD localizer (dot)	.23	.17	7.57	.007
Average localizer exceedance (dot)	.11	.05	6.15	.02
Wheel reversals	2.61	1.62	9.16	.003
RMS wheel (deg)	2.24	1.79	11.46	.001

Table 5-14. Sidestep Landing Fix-to-BC Results for Group

Variable	Mean	Differences			Stats	
		I-II	II-III	I-III	F(2,114)	p
Max heading deviation (deg)	6.10	2.47*	-1.35*	1.12	11.28	<.0001
Average heading exceedance	.44	.55*	-.15	.40*	8.78	.0003

Variable	Mean	Differences			Stats	
		I-II	II-III	I-III	F(2,114)	p
(deg)						
Column reversals	1.33	.85	.38	1.23*	4.79	.01
Wheel response BW (Hz)	.12	.01	.02	.03*	4.52	.01

* indicates significant difference (p<.05)

Table 5-15. Sidestep Landing Fix-to-BC Results for Phase (I=Evaluation, II=Training, III=Quasi-Transfer Testing)

Breakout-of-Clouds to the Upward-Gust

The Breakout-of-Clouds to the Upward-Gust (BC-to-Gust) segment was the flight segment where sidestepping occurred. For this segment, 20 dependent variables were used in the MANOVA, as follows:

Performance

- STD heading, bank, and pitch angle
- Maximum heading and bank angle during sidestep
- Average airspeed exceedance
- Sidestep rate (the lateral speed going from 800 ft to within 200 ft lateral distance from the centerline of runway 36 Right)
- Sidestep lateral overshoot (the rightmost lateral distance from the centerline of runway 36 Right after sidestep)
- Maximum, STD, and average exceedance of glide slope deviation

Behavior

- RMS and number of reversals of column, wheel, and pedal
- Column, wheel, and pedal response bandwidths

The analyses of this segment again yielded significant overall Group and Phase effects (Wilks' Lambda Λ=.72, F(20,95)=1.86, p=.02, and Λ=.25, F(40,190)=4.72, p<.0001, respectively) with no interaction (Λ=.73, F(40,190)<1, p>.10). The only significant Group effect for this flight segment was the higher wheel activity of the Motion group compared with the No-Motion group (Table 5-16). This difference, however, did not result in any difference in the flight-precision performance between the two groups. The effect on Phase (Table 5-17) showed that Training, regardless of the motion configuration, had the following significant effects on Quasi Transfer: better directional performance (heading), more accurate glide-slope tracking, lower control activity (column, wheel, pedal) with lower wheel response bandwidth, and less aggressive sidestep (lower sidestep rate and lower sidestep overshoot).

Variable	Mean		Stats	
	Motion	No-motion	F(1,114)	p
Wheel reversals	2.89	2.23	7.07	.009
RMS wheel (deg)	2.74	2.32	10.19	.002

Table 5-16. Sidestep Landing BC-to-Gust Results for Group

Variable	Mean	Differences			Stats	
		I-II	II-III	I-III	F(2,114)	p
Max heading (deg)	10.62	.89	.75	1.64*	3.43	.04
Sidestep rate (ft/s)	50.34	11.69*	-5.08	6.61*	11.15	<.0001
Sidestep lateral overshoot (dot)	.46	.41*	-.15	.27	5.84	.004
STD glide slope (dot)	.28	.07*	.03	.10*	8.07	.0005
Max glide slope (dot)	.91	.19	.03	.22*	4.70	.01
Average glide slope exceedance (dot)	.09	.05	.03	.08*	3.09	.05
Wheel reversals	2.56	.85*	.06	.91*	5.65	.005
Column reversals	1.90	.76	.65	1.41*	5.19	.007
Wheel response BW (Hz)	.085	.005	.05*	.05*	10.91	<.0001
RMS pedal (in)	.15	.08*	-.01	.06*	5.02	.008

* indicates significant difference (p<.05)

Table 5-17. Sidestep Landing BC-to-Gust Results for Phase (I=Evaluation, II=Training, III=Quasi-Transfer Testing)

Upward-Gust to Touchdown
The Upward-Gust to Touchdown (Gust-to-TD) segment is considered the most diagnostic flight segment of the Sidestep Landing for the emergence of an effect of motion, because in this segment the pilots had to respond quickly and appropriately to maintain precise

flight path. The 20 dependent variables used for MANOVA of this segment are as follows:

Performance

- STD heading, bank, and pitch angles
- Roll and yaw activities
- Average airspeed exceedance
- STD localizer deviation
- STD and average exceedance of glide slope deviation
- Touchdown descent rate
- Touchdown distance

Behavior

- RMS and number of reversals of column, wheel, and pedal responses
- Column, wheel, and pedal response bandwidths

As in the other segments, the overall Group and Phase effects were significant for this segment (Wilks' Lambda Λ=.62, F(20,95)=2.93, and Λ=.37, F(40,190)=3.08, respectively, both p<.001). Again, they didn't interact with each other (Λ=.66, F(40,190)=1.10, p>.10), so all Group effects were present during all phases (i.e., even when both groups had motion), and both groups were equally affected by Phase.

Group effects were observed on three of the 20 individual variables analyzed for this particular segment (Table 5-18). The two groups appear to use different TD strategies regardless of Phase: The Motion group landed softer, but at a farther distance from the runway threshold (yet within the landing box) compared to the No-Motion group. The landing box is 500 ft to 3000 ft from the runway threshold. The No-Motion group again employed higher pedal-response bandwidths than the Motion group.

Variable	Mean		Stats	
	Motion	No-motion	F(1,114)	p
Pedal response BW (Hz)	.04	.08	14.08	.0003
TD distance (ft)	1660	1435	12.09	.0007
TD descent rate (ft/min)	285	327	6.02	.02

Table 5-18. Sidestep Landing Gust-to-TD Results for Group

Both groups significantly improved on nine variables across phases for the Gust-to-TD segment (Table 5-19), showing again that Training was effective. For flight-precision performance, improvement was only observed in glide-slope tracking (lower deviation STD and average exceedance). In behavior, progressively with Phase, pilots were found to significantly reduce their yaw activity, wheel reversals, wheel and pedal RMS, and wheel, pedal, and column response bandwidths.

Variable	Mean	Differences			Stats	
		I-II	II-III	I-III	F(2,114)	p
Yaw activity (deg/s)	.41	.07*	-.01	.06*	4.58	.01
STD glide slope deviation (dot)	.56	.05	.04	.09*	4.76	.01
Glide slope exceedance (dot)	.23	.10	.03	.12*	4.08	.02
Wheel reversals	8.07	1.84*	.82	2.66*	6.51	.002
RMS wheel (deg)	2.93	.46*	-.06	.40	4.52	.01
Wheel response BW (Hz)	.15	.02	.07*	.09*	18.56	<.0001
Column response BW (Hz)	.10	.05*	.04	.08*	11.61	<.0001
RMS pedal (in)	.40	.12*	-.04	.07	7.72	.0007
Pedal response BW (Hz)	.06	-.03	.04*	.02	7.08	.001

* indicates significant difference (p<.05)

Table 5-19. Sidestep Landing Gust-to-TD Results for Phase (I=Evaluation, II=Training, III=Quasi-Transfer Testing)

Summary

The sidestep-landing maneuver was analyzed in three segments, Approach-Fix-to-Breakout-of-Clouds, Breakout-of-Clouds-to-Upward Gust segment, and Upward-Gust-to-Touchdown. All pilots improved across phases, regardless of Group.

During the Fix-to-BC segment, the No-Motion pilots had better directional control using fewer wheel inputs than the Motion group, just like for the PIA. The lower wheel-activity effect for the No-Motion group also held during the BC-to-Gust segment, but was not accompanied by any performance differences.

For the most challenging Gust-to-TD segment, however, the increased pedal-response bandwidth for the No-Motion group returned. Also, the Motion pilots landed slightly softer than the No-Motion pilots even when all pilots had motion, but also slightly further away from runway threshold.

5.3.3.8 Discussion

Takeoff maneuvers

The most important result for the takeoff maneuvers was the faster pedal reaction time to the V_1 cut of the Motion compared with the No-Motion group during Evaluation and Training. This does point to an early alerting function of the enhanced motion, providing sufficient lateral acceleration cues, as this result was not found in the First Study using "as is" motion. Despite the fact that PFs were told which engine failure to expect during Training, the No-Motion group continued to be unable to match the reaction time of the Motion group. Once the No-Motion group did quasi-transfer to motion, however, it was immediately able to avail itself of the motion cues, and the pedal reaction time and related differences disappeared. That the pedal reaction time advantage during the V_1 cut was not replicated for the V_2 cut might be explained by the higher altitude during the V_2 cut, which renders a response less time-critical, and the reduced visual reference to the ground, which may have led to consultation of the instruments before responding.

One curious result for the V_2 cut is that at Quasi Transfer, the pedal reaction time of the Motion group is slower than for the No-Motion group. Further statistical examination showed that both groups do quasi-transfer the reaction time improvement achieved during Training, but the Motion group less completely than the No-Motion group. This may be due to fatigue of the Motion group, which in the No-Motion group may be counteracted by the emergence of motion. Another indication that fatigue may have been a factor with the V_2 cut is the number of variables that significantly improved during Training, but then significantly deteriorated at Quasi Transfer regardless of Group. This doesn't happen with any of the other maneuvers.

Landing maneuvers

The differences in landing strategy for the Sidestep Landing between the two groups make intuitive sense. The Motion group appears to use the vertical acceleration cues to arrest sink rate, resulting in softer landings but farther-from-runway-threshold touchdowns than the ones of the No-Motion group. The fact that these performance differences were not replicated for the Precision Instrument Approach might be explained by the lower visibility and the shifting head- and tailwinds distracting the Motion group from taking advantage of the vertical acceleration cues.

The more striking result from the landing maneuvers is the consistent finding of lower control activity with higher flight precision for the No-Motion group, and that this finding persisted even at Quasi Transfer to the simulator with motion. This shows that even when the No-Motion group is exposed to motion cues, it continues the steady control strategy adopted without motion cues. This was found for all segments of both maneuvers, with the exception of Sidestep Landing Gust-to-TD. The lower control activity refers to the wheel only. Pedal and column inputs were usually the same.

Pedal-response bandwidth showed some interesting patterns. There were no differences between the two groups during the "easier" segments of the Sidestep Landing before the upward-gust disturbance. However, during the V_2 cut, both segments of the PIA, and the Gust-to-TD segment of the Sidestep Landing, the pedal-response bandwidth of the No-Motion group was higher than for the Motion group. Finally, the one case where the Motion group had higher pedal-response bandwidth than the No-Motion group was during the V_1 cut, but only before both groups had motion, the difference disappeared at Quasi Transfer due to the No-Motion group significantly increasing its pedal-response bandwidth. In all cases but the V_2 cut, which didn't reveal any performance differences between groups, whenever there was a difference between groups in pedal-response bandwidth, the group with the higher bandwidth also had better directional control.

These results are different from some of the previous tracking studies that have found increased control activity when motion was reduced (Schroeder, 1999). Other studies, however, are consistent with the results of the present study (Scanlon, 1987; Mulder, Chiecchio, Pritchett and van Paassen, 2003). Whether or not control activity increases or decreases as platform motion varies depends on several factors. If the pilot has been utilizing motion to improve the stabilization of the pilot-vehicle loop, as in Schroeder's helicopter tasks, control activity usually increases as the motion cue becomes less usable. This is explained by the theoretical pilot model offered by Hess (1989). On the other hand, if motion is making the pilot aware of high-frequency disturbances, then control activity can increase when motion cues become more salient, as the pilot attempts to counter those disturbances. For large vehicles, with relatively low control bandwidths, this increased control activity may not translate to improved pilot-vehicle performance. However, this conclusion may depend on task complexity, or, perhaps, task bandwidth (Scanlon, 1987).

5.3.4 Individual Training Progress

As a complement to the assessment of the phase effects in the group analyses, the effect of motion on pilot's individual training progress was assessed by looking at the difference in the percentage of pilots that improved across phases. Variables examined were related to PF control performance (pedal reaction time, STD heading, and STD bank for the takeoff maneuvers; STD localizer and STD glide slope for the landing maneuvers) and control activities (RMS wheel and RMS pedal) from the most important segment of each maneuver.

In this report, reduction in the value of a variable is considered an improvement. While this is true for performance-related variables, it may not be obvious for variables related to control activities. However, because the pilots seemed to aim towards lower RMS values on wheel and pedal during training, this definition of improvement was also applied to the control-activity variables.

Because maneuvers and scenarios, respectively, were repeated during Training and Quasi-Transfer Testing, and did not yield an effect of Trial (see 5.3.3.2), the values of the variables collected during each of these phases were averaged to determine improvement across phases. The criterion for improvement was set to greater than 15% reduction in the average value of variables from one phase to the next. The number of pilots in each group who improved was counted for every variable considered. Fisher's Exact test was then used to examine whether the difference in the percentages of improved pilots between groups was significant.

The purpose of the comparisons of pilots' individual performance and behavior during Evaluation vs. during Training (Phase I vs. Phase II) and during Evaluation vs. during Quasi-Transfer Testing (Phase I vs. Phase III) for each group was to determine whether pilots improved across phases, and whether the nature of training (with or without motion) affected the percentage of pilots that improved. The purpose of the comparison of pilots' individual performance and behavior during Training with their performance and behavior during Quasi-Transfer Testing for each group was to determine whether the nature of transfer, from the simulator without motion to the simulator with motion for the No-Motion group or from motion to motion for the Motion group, had a differential effect on quasi-transfer of the performance and behavior of individual pilots. The summary of the results for each maneuver is given below.

5.3.4.1 V_2 Cut

Table 5-20 presents the percentage of improvement in the Motion group compared with the percentage of improvement in the No-Motion groups between Evaluation and Training (I to II), Evaluation and Quasi-Transfer Testing (I to III), and between Training and Quasi-Transfer Testing (II to III). Five significant differences were found, all in favor of the No-Motion group.

Only two of these differences were between Training and Quasi-Transfer Testing, the comparison that would indicate that the fact of adding motion had an effect on certain control activities. However, they were only marginally significant, and neither of the improvements was strong enough to reach significance at the group level, where there were no corresponding Group effects (see 5.3.3.4).

Two differences in percent improvement were found between Evaluation and Quasi-Transfer Testing. One was for pedal-reaction time. This difference was reflected in the Group comparisons, which showed that the No-Motion group improved its mean pedal-reaction time significantly between Evaluation and Quasi-Transfer Testing (the Motion group had lost some of the improvement gained during training, so any difference between the means disappeared at Quasi Transfer) (see Table 5-2). The other was a marginally higher percentage of improved pilots for pedal RMS. Finally, the percentage of the No-Motion pilots improving their pedal-response reaction time also tended to be higher than the one for the Motion pilots from Evaluation to Training (at the group level, both improvements had been significant).

Variable	I to II			I to III			II to III		
	% Improved		Fisher's Exact *p*	% Improved		Fisher's Exact *p*	% Improved		Fisher's Exact *p*
	Mot	No-Mot		Mot	No-Mot		Mot	No-Mot	
Pedal RT	65	90	.06	40	80	.01	10	30	.12
STD heading	60	50	.37	40	45	.50	20	35	.24
STD bank	70	55	.26	40	50	.37	15	20	.50
RMS Wheel	65	40	.10	30	45	.26	0	20	<.06
RMS Pedal	55	50	.50	35	60	.07	0	20	<.06

Table 5-20. Fisher's Exact Statistics of Group Differences in Percentage Improvement Between Two Phases for V_2 Cut (I=Evaluation, II=Training, III=Quasi-Transfer Testing)

5.3.4.2 V_1 Cut

As can be seen from Table 5-21, again all of the now six significant differences were in favor of the No-Motion group. Four of these involved the pedal; there was a significantly higher percentage of No-Motion pilots who shortened their pedal reaction time and lowered their pedal activity from Evaluation to Quasi-Transfer Testing as well as from Training to Quasi-Transfer Testing compared to the Motion pilots. These differences reflect the finding in the group data that the No-Motion pilots' pedal-reaction time remained stagnant as long as there were no motion cues alerting them of the V_1 cut, but then immediately caught up with the motion pilots during Quasi-Transfer Testing with motion cues. Similarly, as long as there were no motion cues, the No-Motion pilots had significantly higher pedal RMS compared to the Motion pilots, a difference that also disappeared with quasi transfer to motion.

The improvement in the pedal-reaction time may also have effected an improvement in heading and bank control, as there was a marginally higher percentage of No-Motion pilots who lowered bank angle and heading STD from Evaluation to Quasi Transfer. However, the group data show that the difference between groups in heading control had disappeared already during Training, and there were no group differences in bank-angle STD.

Variable	I to II			I to III			II to III		
	% Improved		Fisher's Exact *p*	% Improved		Fisher's Exact *p*	% Improved		Fisher's Exact *p*
	Mot	No-Mot		Mot	No-Mot		Mot	No-Mot	
Pedal RT	30	55	.21	20	80	.0002	0	60	.00002
STD heading	35	55	.17	40	70	.06	40	60	.17
STD bank	30	40	.37	35	65	.06	40	50	.37
RMS Wheel	35	45	.37	40	45	.50	45	40	.50
RMS Pedal	25	40	.25	20	85	.00004	5	50	.002

Table 5-21. Fisher's Exact Statistics of Group Differences in Percentage Improvement Between Two Phases for V_1 Cut (I=Evaluation, II=Training, III=Quasi-Transfer Testing)

Comparison with First Study

Despite the fact that no pedal-reaction-time advantages were found for the Motion group in the First Study, the individual training data suggest that transferring to motion may have helped the No-Motion pilots improve their heading performance and reduce their pedal control activity. Comparisons of the percent of Motion and No-Motion pilots that improved between phases show that a higher percentage of No-Motion pilots improved in heading STD ($p<.10$)) and pedal RMS ($p<.05$) than the Motion pilots from Last Training to Quasi Transfer (see Table A1-5, note the differences in comparison procedures). The improvements were not large enough to result in a difference at the group level. Similar differences in individual pedal RMS improvement were also observed in the Second Study between Training and Quasi-Transfer Testing, but not for heading STD improvement.

A second indication from the First Study that motion might assist pilots to improve pedal control for the V_1 cut may be the marginal difference in percent improvement from First to Last Training in pedal RMS, although it did not effect a performance improvement. In this case, a marginally higher percentage of Motion pilots reduced the number of pedal reversals than No-Motion pilots. This result was not replicated in the Second Study.

For the RTO maneuver, no differences between the Motion and No-Motion groups were found in percentage improvement from the First to Last Training, from the first training to Quasi Transfer, and from the last training to Quasi Transfer (see Table A1-6).

5.3.4.3 Precision instrument approach

During the Approach-Fix-to-Decision-Height segment of the Precision Instrument Approach, it was the Motion group that generally showed a higher percentage of improved pilots than the No-Motion group in four cases, although two of these differences were only marginally significant. More Motion pilots lowered their pedal activity (lower RMS) between Evaluation and Training and marginally more between Evaluation and Quasi-Transfer Testing (Table 5-22). In this case, training might have helped the Motion pilots recognize that too much counteraction to the disturbance-motion cues from the shifting winds reduces flight-path precision. However, although there was one marginally significant higher percentage of the Motion group improving localizer STD from Training to Quasi Transfer, the group analyses show that the Motion pilots never caught up with the No-Motion pilots on pilot-vehicle performance (see Table 5-10).

Variable	I to II			I to III			II to III		
	% Improved		Fisher's Exact *p*	% Improved		Fisher's Exact *p*	% Improved		Fisher's Exact *p*
	Mot	No-Mot		Mot	No-Mot		Mot	No-Mot	
STD LOC	70	60	.37	60	55	.50	30	60	.06
STD GS	65	50	.26	60	55	.50	30	40	.37
RMS Wheel	65	60	.50	60	40	.17	20	30	.36
RMS Pedal	70	35	.03	65	35	.06	30	50	.17

Table 5-22. Fisher's Exact Statistics of Group Differences in Percentage Improvement Between Two Phases for Precision Instrument Approach (I=Evaluation, II=Training, III=Quasi-Transfer Testing)

5.3.4.4 Sidestep landing

For Sidestep Landingfrom Gust-to-Touchdown, the Motion-group improvement percentages were higher than the ones of the No-Motion group for localizer and glide-slope tracking between Evaluation and Training. Some of the motion pilots that had improved seem to have lost this improvement during the next phase, because the effect is reduced to a trend for localizer and entirely lost for glide slope when comparing Evaluation not with Training, but with Quasi-Transfer Testing (Table 5-23). Marginally more Motion than No-Motion pilots improved in localizer tracking from Evaluation to Quasi Transfer, but may be that is why also marginally fewer reduced their pedal activity (RMS). None of these differences, however, were reflected in the analyses by group (Table 5-18).

Variable	I to II			I to III			II to III		
	% Improved		Fisher's Exact *p*	% Improved		Fisher's Exact *p*	% Improved		Fisher's Exact *p*
	Mot	No-Mot		Mot	No-Mot		Mot	No-Mot	
STD LOC	45	15	.04	65	35	.06	40	50	.37
STD GS	65	30	.03	50	45	.5	20	40	.15

Variable	I to II			I to III			II to III		
	% Improved		Fisher's Exact *p*	% Improved		Fisher's Exact *p*	% Improved		Fisher's Exact *p*
	Mot	No-Mot		Mot	No-Mot		Mot	No-Mot	
RMS Wheel	55	70	.26	50	35	.26	15	20	.5
RMS Pedal	60	70	.37	30	60	.08	5	5	.75

Table 5-23. Fisher's Exact Statistics of Group Differences in Percentage Improvement Between Two Phases for Sidestep Landing (I=Evaluation, II=Training, III=Quasi-Transfer Testing)

Table 5-23 also shows that the quasi transfer from motion to motion vs. from a fixed-base simulator to the (same) simulator with motion did not have an effect, as there was no difference in the percentage of improvement between the groups from Training to Quasi-Transfer Testing.

5.3.4.5 Discussion

For the takeoff maneuvers, it was the No-Motion pilots who showed higher percentages of improvement. In fact, the percentage of Motion pilots improving never exceeded the one of No-Motion pilots. One argument against interpreting this as an advantage of the No-Motion simulator configuration for training would be that at least some of the Motion pilots, for the takeoff maneuvers, have reached their performance and/or behavioral peak. Then, however, there should be a performance advantage of the Motion pilots, at least for those variables where an increased number of No-Motion pilots improves, and in the earlier of the two compared phases. This is indeed true for the V_1 cut, where a slight majority of the improvement advantages occurred, but not for the V_2 cut. The final result of training was that the No-Motion group had caught up with any initial advantages of the Motion group by the time it quasi-transferred to the simulator with motion.

For the landing maneuvers, it was the Motion group that showed more individual training progress, with the exception of RMS pedal during the side step. However, this was restricted to two variables for each landing maneuver. The final result of training was that the Motion group was never able to catch up with the initial advantage of the No-Motion group, not even when the No-Motion group also transferred to motion, and that any other differences persisted.

5.3.5 Pilot Grades

5.3.5.1 Determination and calculation

The pilot grades for each maneuver trial were determined based on the feedback displays. A set of criteria based on the FAA PTS was developed to determine the grades. These criteria can be seen in 10. The grade for each criterion (criterion grade) varied from 1 to 5 with 1 being the worst and 5 being the best. In general, the criteria looked at the ability of the PFs to stay within the PTS bounds, the magnitude of the out-of-bound deviations (if any), the locus of occurrence of any out-of-bound deviations relative to a specific event such as engine failure or runway threshold crossing, and control steadiness. The final grade for each maneuver was calculated by combining the criterion grades using specific weights, as also described in 10.

Two evaluators independently determined the criterion grades from the recorded performance-feedback variables of each maneuver without knowing whether the platform motion was on or off. The resulting criterion grades from these evaluators were compared and a third evaluator settled any differences found in the criterion grades from the two evaluators. This was all done to avoid mistakes or data misreading especially in boundary cases.

5.3.5.2 Grade analysis

The effects of Group and Phase on the pilot grades was determined using Analyses of Variance (ANOVA). Each maneuver was analyzed separately and the grades were averaged across the maneuvers/scenarios in Training and Quasi-Transfer Testing phases before analysis. The results are summarized below.

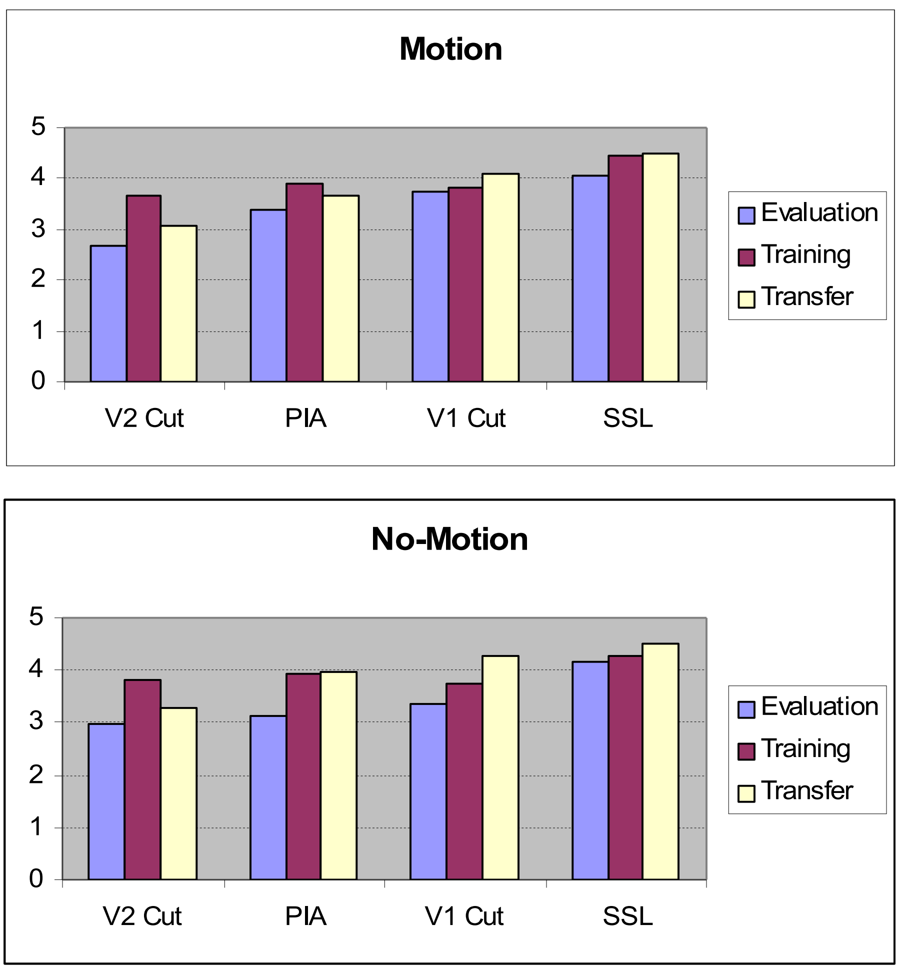


Figure 5-13. Grade Means by Phase and Maneuver

The means of the grades for each group, phase, and maneuver are shown in Figure 5-13. First of all, there was no interaction between Group and Phase for any of the four maneuvers (V_2 cut, PIA, V_1 cut, Side Step Landing $F(2,114) \leq 1.18$). Group did not have a significant effect on the grades, except for the V_2 cut where a marginally significant difference between groups was observed ($F(1,114)=3.17$, $p<.10$). In this case, the No-Motion group had marginally better grades than the Motion group (3.36 vs. 3.14).

Phase significantly affected the pilot grades for both groups in all four maneuvers (Table 5-24). In most cases, the grades improved progressively with Phase, except for the V_2 cut, where the grades significantly deteriorated between Training and Quasi-Transfer Testing. This is another indication that the V_2 cut results may have been affected by pilot fatigue (see 5.3.3.8). The progressive improvement in grades observed in the other cases showed that the training performed benefited both groups.

Maneuver	Mean	Differences			Stats	
		I-II	II-III	I-III	F(2,114)	p
V_2 Cut	3.25	-.92*	.56*	-.36	18.55	<.0001
PIA	3.66	-.66*	.10	-.56	4.00	.02
V_1 Cut	3.84	-.24	-.39	-.63*	5.90	.004
SSL	4.33	-.26*	-.12	-.38*	7.70	.0007

* indicates significant difference (p<.05)

Table 5-24. Grade Results for Phase (I=Evaluation, II=Training, III=Quasi-Transfer Testing)

5.3.5.3 Discussion

The purpose of the pilot grades was to independently verify the validity of the linear combination of the many different dependent variables measured during the experiment calculated by the MANOVAs. Using an approach based on the FAA's Practical Test Standards, the Phase effects were well replicated, showing the validity of the MANOVA procedure. The Group effects were too small to be captured by applying the PTS.

5.3.5.4 Comparison with First Study

During the First Study, a counterbalanced set of I/Es that were kept unaware of the purpose of the experiment or the motion status of the simulator graded each maneuver. Platform motion did not affect Evaluation in the simulator, nor did it affect the grades at Quasi Transfer to the simulator with motion. The latter was true when comparing the group means or the number of low vs. high grades in each group (i.e., grades of 1 and 2 vs. grades of 3 and 4). However, as can be seen in , there was one single analysis where motion appears to have affected I/E grades. During Quasi-Transfer Testing, I/Es gave more grades of 1 to V_1 cuts flown by pilots trained without motion than to pilots with motion. This was only true when comparing the percentages of grades 1 and 2, both groups received an equal number of grades 3 and none of the pilots received a grade of 4. Improvement across the two phases can also be seen for both groups. Despite this single effect of motion, there was no effect of motion on the course of Training or on the amount of Training required before reaching the criterion needed to move to Quasi-Transfer Testing. Overall, the grades did show that the pilots improved across the maneuvers, but similarly for the two groups (see Bürki-Cohen et al., 2001). The true I/E grades of the First Study thus yielded similar results as the grades constructed from the feedback displays in the Second Study.

5.4 Opinions from Questionnaires

5.4.1 Data Analysis Overview

The responses to the Pilot-Flying questionnaires were examined to determine whether there were differences in how the Motion and the No-Motion groups compared the simulator to the airplane or to the last simulator flown on different properties (see 6). The Pilot-Not-Flying questionnaire responses were examined for differences between how the two groups compared to average pilots on various performance and behavior variables (see 7). As appropriate, the effects of factors such as Phase (Evaluation, Training, Quasi-Transfer Testing), type of Control input (aileron, rudder, etc), and type of Maneuver were also analyzed. Finally, because most average responses were very close to “same as” the simulator/airplane/average pilot, one-sample T-tests determined whether the PF/PNF ratings were significantly different from the “same as” rating. These tests were performed separately for each questionnaire and question, using the mean ratings for each control or maneuver. They were performed with both groups combined when there was no effect of Group in any of the analyses, and separate if there was a significant or a trend of a difference between groups. As in the rest of this report, any difference between conditions was considered statistically significant if it had a probability of chance occurrence lower than five percent ($p<.05$) given no effect of the condition variable. Differences where the probability was larger than five but smaller than ten percent ($.05<p<.10$) were considered a statistical trend.

5.4.2 Pilots Flying

5.4.2.1 Data Analyses

For general properties such as Acceptability, Comfort, and Physical and Mental Workload, PFs were asked to give a general rating without distinguishing between type of Control or Maneuver. These ratings were analyzed using ANOVAs with Group (Motion vs. No-Motion evaluated/trained) as a two-level between-subjects factor and Phase (Evaluation, Training, and Quasi-Transfer Testing) as a three-level within-subjects factor.

For properties such as Handling Qualities, Control Feel and Control Sensitivity, PFs gave both an overall rating and specific ratings for each type of Control. For these, first the Group-by-Phase ANOVA described above was performed with the overall rating as the dependent variable. Then, separate ANOVAs for each questionnaire (i.e., Phase), with Group as a two-level between-subjects factor and type of Control as a within-subjects factor (varying between five and eight levels including the overall rating) were performed. To prevent inflation of degrees of freedom when calculating the main effect of motion in these comparisons, the degrees of freedom were adjusted so that each PF was counted only once instead of separately for each control rating.

For Control Strategy and Technique and Gaining Proficiency, PFs gave a rating for each Maneuver in addition to the overall rating. Here, the Group-by-Phase ANOVA with the overall ratings was followed by separate ANOVAs for each questionnaire examining the effects and interactions of Group and Maneuver. Maneuver was treated as a within-subjects factor. The same Group-by-Maneuver ANOVAs were used to analyze the answers on Performance and Other Cues, where no overall rating was requested. PFs were not asked to rate their performance after Training, where they had received performance feedback, and they were not asked about their ease of Gaining Proficiency after Evaluation, when they had been exposed to each scenario only once. Again, the degrees of freedom were adjusted by counting each pilot only once instead of for each maneuver when calculating the main effect of motion.

5.4.2.2 Were there any differences between the Motion and No-Motion groups?

Only eight of the 26 analyses found an effect of the Group (i.e., Motion vs. No-Motion) variable, and half of these effects were only a trend ($p<.10$). They involved less than half of the properties examined (5 of 11). Moreover, for Handling Qualities, it was the No-Motion group that perceived the simulator significantly more similar to the airplane than the Motion group, but only for the ratings after Training analyzed in the separate Group-by-Control ANOVA. On a scale from -3 (much worse than the airplane) to +3 (much better than the airplane),[4] both groups rated the simulator as less than "slightly different" from the airplane, but the mean rating of the No-Motion group was higher than the one of the Motion group (-.18 vs. -.5; $F(1,38)=4.82$, $p<.05$). The four remaining properties with their mean ratings are listed below:

- For Control Feel, the Group-by-Phase ANOVA showed that the Motion group rated it significantly more like the airplane than the No-Motion group (-.24 vs. -.68 where -3 means "much lighter" and +3 means "much heavier than airplane"; $F(1,114)=8.00$, $p<.01$). The Group-by-Control ANOVAs after each phase found only trends of a Group effect, and only after Training and Quasi-Transfer Testing ($F(1,38)=3.99$ for Training and 4.01 for Quasi-Transfer Testing, $p<.06$).
- For "Other Cues," the Group-by-Maneuver ANOVA after Training showed that the No-Motion pilots perceived them significantly less like the airplane than the Motion pilots (3.03 vs. 3.54, where 4 means "the same as" and 1 "very different than in the airplane;" $F(1,38)=4.78$, $p<.05$). After Evaluation, this difference had only been a trend ($F(1,38)=3.13$, $p<.10$).
- For Performance, the Group-by-Maneuver ANOVAs showed that the Motion pilots rated their performance significantly more like in the airplane than the No-Motion pilots did, but only after Evaluation (-.68 vs. –1.16 on a scale from –3 to +3; $F(1,38)=4.31$, $p<.05$).
- For Gaining Proficiency, the Group-by-Maneuver ANOVAs found a trend for the Motion pilots to rate their Gaining Proficiency as easier than the No-Motion pilots did, but only after Training (.21 vs. -.32 on a scale from –3 to +3; $F(1,38)=3.30$, $p<.10$).

[4] Note that the scales from 1 to 7 in the questionnaires, where 4 was labeled as equivalent to the airplane, were transformed to scales from –3 to +3 with 0 meaning equivalent to the airplane.

There were no interactions between Group and Phase ($F(2,113\text{-}114) \leq 1.57$). This means that any effects found in the Group-by-Phase ANOVAs were present in all phases, even during Quasi-Transfer Testing when both groups had motion, and that no Group main effects were masked by Phase effects.

There were also no interactions between Group and Maneuver or Type of Control (all $F_{Group\ x\ Maneuver}$ either $F(3,150\text{-}152) \leq 1.77$ or $F(4,190)<1$, all $F_{Group\ x\ Control}$ either $F(7,286\text{-}303) \leq 1.28$ or $F(6,265\text{-}266)<1$ or $F(4,188\text{-}190)<1$; all $p>.10$). This means that any motion effects found in the Group-by-Maneuver and Group-by-Control ANOVAs held for all controls and maneuvers, and that no potential motion main effects were masked by control or maneuver effects, respectively.

In summary, these results do not lead to the conclusion that motion was a powerful variable affecting PF's perception of the simulator, for two reasons. First, they show that the vast majority of the comparisons was unaffected by whether the groups had or had not been trained with motion cues (all $F(1,112\text{-}114) \leq 1.73$ or $F(1,38\text{-}39) \leq 2.71$, $p>.10$). Notably, none of the comparisons relating to the following properties were at all affected by or interacted with Group (all $p>.10$):

- Acceptability (compared with the last simulator flown; all $F(1 \text{ or } 2,114)<1$)
- Physical Comfort (compared with the last simulator flown; all $F(1 \text{ or } 2,113) \leq 1.66$)
- Mental and Physical Workload (compared to the airplane; all $F(1 \text{ or } 2,114) \leq 1.03$)
- Control Sensitivity (defined as "the amount of response generated by the control actions" and compared with the airplane; all $F(1 \text{ or } 2,112) \leq 1.45$, all $F(1,38)<1$, all $F(4,188\text{-}190)<1$)
- Control Strategy and Technique (compared with the airplane; all $F(1,38) \leq 1.04$, all $F(3,152) \leq 1.77$, all $F(4, 190)<1$) (all compared with the actual airplane)

The lack of a difference for Physical Comfort is especially important because it removes any concerns that the lack of motion would induce motion sickness. There are several theories that would support this prediction, most are based on the stipulation that motion sickness arises when there is a conflict between vestibular and visual sensations (see, e.g., Oman, 1991). Of course, this conflict was very high during Evaluation and Training for the No-Motion group, yet they reported feeling just as comfortable as the Motion group did.

Second, the status of the motion variable is further weakened by the fact that the differences between groups persisted even after the motion variable was removed. If the presence or absence of motion had greatly affected PFs' ratings, differences between groups should have disappeared once both groups had motion.

Comparison with First Study

The First Study had found three differences between the ratings by the crews in the two groups (remember that in the First Study, each Captain flying was paired with a new PNF that knew nothing about the study). In each of these cases, it was the *absence* of motion that led to higher ratings (see Bürki-Cohen et al., 2001, for statistics).

- After Quasi Transfer to motion, the No-Motion PFs rated Control Precision as less worse than in the airplane than the Motion group. This was due to the Motion group rating the simulator worse after Quasi-Transfer Testing, while the No-Motion PFs gave equivalent ratings.
- There was also a trend for the No-Motion PF to perceive Gaining Proficiency easier in the test simulator compared to the last simulator flown (which was the same simulator with the motion on), compared to the Motion group. The Motion PF perceived no differences between the test simulator and the last simulator flown (which was the same simulator in the same configuration).
- After Training, the No-Motion PNFs rated their PFs as having better control precision than the Motion PNFs rated their PFs.

In summary, the First Study had found even fewer differences between the two groups, and these differences did not show a preference for motion.

5.4.2.3 Did Pilots Flying recognize the absence of motion?

Although the question of "motion" was never directly addressed in the questionnaires, pilots had many opportunities to comment on their perception of the simulator motion. For pilots that didn't mention motion when evaluating the simulator's Control Feel and Sensitivity, Handling Qualities, and overall Acceptability, they could mention it when commenting on their own Performance, Workload, or Comfort. If they failed to do so, a final opportunity was offered when they were asked to compare "Other cues" provided by the simulator with those experienced in the airplane. Pilots were encouraged to make comments and asked to elaborate on all ratings that expressed a difference between the test simulator and the airplane/last simulator flown, in the space provided on the questionnaires (see 6).

Nevertheless, not all of the 20 No-Motion pilots appeared to notice the lack of motion, despite the fact that any reference to the quality of the motion was counted as an indication that the No-Motion pilots did perceive the absence of motion (see 11). Thirteen commented on the quality of the motion on the questionnaire administered after Evaluation, but not all of these appeared to have noticed that motion was entirely turned off. Comments ranged from noting that the motion was "not rough enough" from one of the first pilots participating to "Motion off is disorienting and reduces feedback. My head was almost spinning once breaking out on the ILS [Instrument Landing System]" from one of the final participants who was a simulator instructor in addition to flying the line.

Three No-Motion pilots realized that something was wrong with the motion only after Training. One asked whether there would be "probably better yaw feel in aircraft when you lose an engine?" Another noted the absence of motion during landing: "No ground feel. Only indication of landing is spoiler." The third wrote that he "[d]id not feel yaw."

Four No-Motion pilots gave no indication that they noticed anything amiss with the motion stimulation provided by the simulator. Three of these never commented on the motion, and one indicated the potential for physical discomfort with motion after the second Quasi-Transfer Test.

By the time the last six pilots (all from the same airline as many of the earlier pilots) were tested, word may have gotten out regarding the purpose of the experiment. In contrast to the first 14 No-Motion pilots, where never more than two consecutive pilots had commented on motion on the first questionnaire administered after evaluation, each of these final six No-Motion pilots commented on motion after evaluation.

Pilots did not only comment on motion when it was lacking, however. It is worth noting that although the No-Motion pilots made more comments on motion, the Motion pilots made many similar comments. These comments are listed in 12. The parallelism between comments such as "There seems to be more clues as to what is occurring in the aircraft vs. the simulator" from a Motion pilot and "Not as much motion visual cue's (sic)" from a No-Motion pilot suggest that much of both groups' dissatisfaction may be due to inherent simulator limitations regardless of whether hexapod-platform motion is turned on or off.

The complete set of comments on motion, including those from the Motion pilots, is listed in 11 and 12. All other comments are listed in 13 to 22. Comments from the Final Questionnaires are listed in 23 to 28.

Comparison with First Study

The regional-airline captains participating in the First Study were solicited for comments in addition to the ratings only at completion of the flying phase, i.e., after Quasi-Transfer Testing. In general, fewer pilots provided comments than in the Second Study, which may be due to the fact that they were invited to participate just before their jeopardy Line Oriented Evaluation (LOE). So, although they had the option to decline participation in the study, they were in a much more stressful situation than the B747-400 volunteers, who flew in for the experiment and were paid for their participation. More of the No-Motion PFs provided comments (13 vs. 6 Motion PFs), but only one (and none of the Motion PFs) referred to motion, noting its absence during the first set of maneuvers.

5.4.2.4 Did Pilots Flying perceive the test simulator as different than the last simulator flown/airplane?

Despite the difficulty of the maneuvers and the unusually light weight of the simulated airplane, there was no significant difference between average rating and the rating "just like [in] the last simulator [flown]" for Acceptability, Physical Comfort, and Gaining Proficiency (asked only after Training and Quasi-Transfer Testing). The T-tests performed after each Phase showed that these ratings never differed significantly from "just like the last simulator flown" (Acceptability: all $T(39)<1.61$; Physical comfort: all $T(38 \text{ or } 39)<1.05$; Gaining Proficiency: all $T(19)\leq1.62$ (although $T(39)=1.84$, $p<.10$ after Quasi-Transfer Testing); all $p>.10$).

All simulator properties that were compared to the properties of the airplane were considered as different in most but not all comparisons, although all of them less than "slightly" so:

- "Other Cues" were always perceived as different from the airplane (all $T(19)\geq3.13$, $p<.01$).
- Average Handling Quality ratings indicated that they were always perceived as worse than in the airplane ($T(19)>2.26$, $p<.05$).

- Control Strategy and Technique were always rated as different from the airplane ($T(39) \geq 4.49$; $p < .001$).
- Pilots perceived their performance (rated after Evaluation and Quasi-Transfer Testing only) always as worse than in the airplane ($T(19) \geq 3.04$, $p < .01$).
- Physical and Mental Workload were considered higher than in the airplane (all $T(39) \geq 2.15$, $p < .05$).
- Average Control Feel was always perceived as lighter by the No-Motion group ($T(19) \geq 3.12$, $p < .01$), but by the Motion group after Evaluation only ($F(1,19)=2.36$; $p < .05$).
- Average Control Sensitivity was considered higher than in the airplane ($T(39) > 2.74$, $p < .001$).

In summary, the NASA/FAA simulator was perceived as equivalent to the company simulator, but as very slightly different from the airplane.

5.4.2.5 Effects of Phase, Maneuver, and Control

No effects of Phase were found on any of the ratings, and, as mentioned before, Phase and Group effects did not interact (all $F(2,112\text{-}114) \leq 1.57$; $p > .10$). There also were never any effects of Maneuver, and again no interactions with Group (all $F(3,150\text{-}152) \leq 1.77$, $F(4,190) < 1$, all $p > .10$).

There were, however, some effects of type of Control, although they also never interacted with Group. Significant effects of Control were found for Handling Qualities and Control Feel (defined in terms of control loading), and a few trends for Control Sensitivity (defined in terms of the amount of response generated by a control action). These effects are described below.

Handling Qualities were significantly affected by type of Control during Evaluation and Quasi-Transfer Testing (both $F(6,265\text{-}266) \geq 3.52$; $p < .005$). Follow-up Bonferroni tests showed that after Evaluation, this difference was accounted for by yaw control, which was rated worse than any of the other five controls (significantly worse than airspeed, bank angle, heading and altitude, and as a trend than pitch). After Quasi-Transfer Testing, it was airspeed that was rated significantly better than yaw and pitch controls. After Training, the Control type effect on ratings was only a trend ($F(6,266)=1.89$; $p < .10$), and none of the Bonferroni comparisons between type of Control yielded any significance.

The Control Feel ratings were affected by type of Control after Evaluation and Training only (both $F(7,286 \text{ or } 303) \geq 3.20$; $p < .005$). Follow-up Bonferroni tests showed that during Evaluation, rudder was perceived as more lighter than the airplane than pitch trim and throttle, and during Training, it was aileron that was perceived as more lighter than the airplane than pitch and roll trim.

There were only trends of a difference in ratings due to type of Control for Control Sensitivity (all $F(4,188\text{-}190) \geq 2.06$; $p < .10$), but they were there after each phase. However, none of the follow-up tests yielded any significant differences, with the exception of the tests after Quasi-Transfer Testing, which revealed that yaw control was perceived as more more sensitive than in the airplane than the throttle was perceived.

The T-tests on the ratings presented in 5.4.2.4 have already shown that the test simulator was perceived as slightly different from the airplane. The tests described above show that this may be due mainly to yaw and rudder control. This is confirmed also by some of PF's comments (see 11 to 28).

5.4.3 Pilots Not Flying (PNF)

5.4.3.1 Data Analyses

In the PNF questionnaires, the PNFs compared the PFs with an average pilot on Control Performance, Control Strategy and Technique, Physical Workload, and ease of Gaining Proficiency. The Gaining Proficiency comparison was made only after Training and Quasi-Transfer Test 1 and 2. All analyses were done separately for each phase and each question. PNF was included as a two-level between-subjects factor in the analyses to determine PNF differences in opinion. When the questions were asked separately for each maneuver, a Group-by-PNF-by-Maneuver ANOVA was performed. Whenever there was an "overall" or only one rating, Group-by-Phase ANOVAs were performed for this rating. No two-way or three-way interactions between Group and Maneuver, PNF and Maneuver, and Group, PNF, and Maneuver were found. Significant Group-by-PNF interactions were followed up with one-way ANOVAs examining the effect of PNF separately for each Group. Only significant results are given.

5.4.3.2 Did Pilots-Not-Flying perceive differences between the Motion and No-Motion groups?

PNFs (labeled here as PNF1 and PNF2) perceived differences between the two groups in all four parameters they were queried on, i.e., Control Performance, Control Strategy and Technique, Physical Workload, and Gaining Proficiency. These differences were mostly favorable to the No-Motion condition, but at times were due to only one of the two PNFs, while the other didn't perceive any difference between groups.

Control Performance

- For Evaluation, the two PNFs agreed on a higher rating for the No-Motion group than the Motion group ($F(1,142)=5.05$, $p<.05$). In fact, the average rating of .02 for the Motion group on a scale of -3 to +3 indicated that the PNFs perceived the performance of the Motion group as identical to the one of an average pilot. The .19 rating for the No-Motion group, however, indicated that this group was perceived as performing better than the average pilot (see 5.4.3.4).
- For the Training phase, the two PNFs disagreed with each other, resulting in no overall Group effect but a significant Group x PNF interaction ($F(1,144)=17.44$, $p<.0001$). This was due to the fact that with average ratings of .63 vs. .25, PNF1 rated the control performance of the No-Motion group marginally higher than the one of the Motion group ($F(1,17)=3.59$, $p<.10$), while with ratings of -.02 and .33 PNF2 rated that of the Motion group as marginally higher ($F(1, 19)=4.28$, $p<.10$).
- For both Quasi-Transfer Testing trials, PNF1 rated the No-Motion group as better than the Motion group on control performance (average No-Motion ratings .58 and .77, Motion ratings 0 and .23; $F(1, 17)>5.10$, $p<.05$). PNF2 did not perceive differences between the two groups (No-Motion ratings -.02 and -.03, Motion ratings

both 0). So there were effects of Group ($F(1,144)=10.59$; $p<.005$) and PNF-by-Group interactions ($F(1,144)=13.81$; $p<.0005$).

Control Strategy and Technique

There were Group effects only during Training and Quasi-Transfer Testing 2, and only for PNF1, resulting in a PNF by Group interaction (Training: $F(1,36)=4.45$, $p<.05$; Quasi-Transfer Testing 2: $F(1,151)=6.01$, $p<.05$).

On a scale from 1 (very different than average pilot) to 4 (same as average pilot), PNF1 rated the strategy and technique of the Motion group as more different compared to the No-Motion group (3.20 vs. 3.89, after Training; 3.83 vs. 4.0 after Quasi-Transfer Testing 2; $F(1,17)\geq4.50$, $p<.05$). Note that both groups had motion during Quasi-Transfer Testing.

Physical Workload

- For Evaluation, PNF1 (but not PNF2, $F_{Group\ x\ PNF}(1,36)=5.43$, $p<.05$) rated the No-Motion group's workload lower than the one of the Motion group on a scale from –3 (much higher than average PF) to +3 (much lower than average PF) (.20 vs. -.25; $F(1,36)=5.43$, $p<.05$).
- After Quasi-Transfer Test 2, the workload of the No-Motion group was rated lower than the one of the Motion group (.42 vs. 0, $F(1,34)=6.21$, $p<.05$) by both PNFs.

Gaining Proficiency

- During Quasi-Transfer Testing 2, PNF1 perceived the No-Motion group as Gaining Proficiency more easier than an average PF than the Motion group on a scale from –3 (much harder than average PF) to +3 (much easier than average PF) (.80 vs. .15; $F(1,17)=22.02$, $p<.001$), while PNF2 rated the two groups similarly ($F(1,17)<1$). This resulted in a significant Group by PNF interaction ($F_{Group\ x\ PNF}(1,34)=12.11$, $p=.001$).

PNF comments on motion can be seen in 29. All comments were on No-Motion PFs. All but one of these were from PNF2, who commented on half of the No-Motion pilots who flew with him that they tended to overcontrol at quasi-transfer to motion. All other PNF comments are listed in 30 to 33.

Comparison with First Study

While I/Es in the First Study gave equivalent ratings to the two groups after Training with and without Motion, they did give higher control performance ratings to the PFs trained with motion after Quasi-Transfer Testing. Although this may suggest an effect of having been trained with motion on Quasi Transfer, this finding was not supported by the ratings of the crews. It is somewhat consistent, however, with the single Motion group difference found in the V_1 cut grades (see 5.3.5.4). The Second Study found no such difference in performance ratings favoring the Motion group.

5.4.3.3 Effects of Pilot-Not-Flying and Maneuver

Most of the effects of PNF have been discussed already in 5.4.3.2, because they interacted with Group. The effects of PNF that did not interact with Group are discussed below:

- For Control Strategy and Technique, during Evaluation, PNF1 perceived the PFs as more different compared to an average PF than PNF2 did ($F(1,142)=12.45$, $p<.001$).
- For Physical Workload, PNF1 rated the PFs as having lower Physical Workload compared to an average PF than PNF2 did ($F(1,34)=6.21$, $p<.05$).

The effects of PNF described here coupled with the many interactions with Group described in 5.4.3.2 suggest that PNF1 employed a more sensitive rating scheme than PNF2.

Maneuver did not have an effect on PNF ratings, except for Control Performance during Quasi-Transfer Testing 1. In this case, the PNFs gave the PFs higher ratings for controlling the Sidestep Landing than for the V_2 cut ($F(3, 144)=3.07$, $p=.03$).

5.4.3.4 Did Pilots-Not-Flying perceive Pilots Flying as different than an average Pilot Flying?

A significant Group effect on PNFs' comparisons of the PFs with an average pilot (see 5.4.3.2) does not necessarily indicate that the PFs were perceived as different from an average pilot. Although some of the PNFs' ratings of the PFs were statistically different from the "same as average PF" rating, all of the average PNF ratings were close to the "same as average PF" or "satisfactory" rating (i.e., never strayed from it even as much as one rating point).

- For Control Performance, the PNFs rated the No-Motion group to be marginally better than "Satisfactory: The same as average PF" in all experiment phases ($T(18)\geq1.84$, $p<.10$). For the Motion group, the PNFs rated the control performance "Satisfactory: The same as average PF," except after Training, where the PNFs rated the Motion group to be better than an average PF ($T(19)=2.93$, $p<.01$).
- For Control Strategy and Technique, the PNFs rated the PFs significantly different than "the same as average PF" in all experiment phases ($T(39)\geq2.33$, $p<.05$).
- For Physical Workload, PNFs rated PFs in each group as "the same as average PF" during Evaluation and Quasi-Transfer Testing 1 ($T(19)\leq1.42$, $p>.10$). During Training and Quasi-Transfer Testing 2, the PNFs perceived the No-Motion group as having a slightly lower than average PF Physical Workload ($T(19 \text{ or } 18)\geq2.70$, $p<.01$), while still considering the Physical Workload of the Motion group to be the same as the one of an average PF ($T(19 \text{ or } 18)\leq1.16$, $p>.10$).
- For ease of Gaining Proficiency of the No-Motion group, PF ratings differed significantly or marginally from "just like average PF" during Training and Quasi-Transfer Testing ($T(19 \text{ or } 18)\geq1.81$, $p<.10$), indicating that it was very slightly easier for the No-Motion pilots than for an average pilot. For the Motion group, however, the PNFs did not perceive differences in the ease of Gaining Proficiency compared to an average PF, except during Training, where they also perceived it as very slightly easier ($T(19)=2.28$, $p<.05$).

In summary, although the PNFs did perceive some differences between the PFs in the experiment and an average PF in various phases of the experiment, these differences were very small.

5.4.4 Summary of Opinions

In general, these data indicate that the perceptions of PFs and PNFs were little affected by the absence of motion. Most importantly, the data show that the simulator was perceived as equally acceptable with and without motion, and that PFs seemed to be equally comfortable in the simulator regardless of its motion status. The former is especially remarkable because the No-Motion group did rate the simulator slightly less like the airplane in terms of "Other cues," presumably because many noticed that motion was lacking. The latter is important because it dispels concerns that the sensory conflict of having visual but not vestibular motion might have resulted in simulator sickness (see, e.g., Oman, 1991).

5.5 Summary of Second Study

The purpose of the Second Study was to determine whether it was possible to improve hexapod motion to a level where it would affect transfer of airline-pilot performance and behavior between simulator and airplane for recurrent training and evaluation. A First Study that had tested the effect of "as is" motion had not found any systematic differences between the effectiveness of the simulator with the motion on and off. For the Second Study, the FAA-NASA CAE Level D Boeing 747-400 simulator was re-engineered to optimize the motion stimulation for the planned test maneuvers. Its lateral acceleration and heave were enhanced trading off rotational motion (mainly yaw) based on findings in the literature. Forty current B747-400 Captains and First Officers participated, aided by two cohort pilots performing non-flying duties. They were divided into two groups, one a Motion group that was evaluated, trained, and quasi-transfer tested in the simulator with the motion turned on throughout, and a No-Motion group that was evaluated and trained with the motion turned off before quasi-transferring to the simulator with motion.

During Evaluation and Quasi-Transfer Testing, the pilots flew full scenarios, departing with an engine failure either just before (V_1 cut) or just after takeoff (V_2 cut), and then continuing with either a precision instrument approach and landing with shifting crosswinds, or a Sidestep Landing with a vertical upward gust just after sidestepping to a parallel runway. To make the maneuvers even more difficult (and pilots did find them very difficult!) the autopilot and autothrottle were inoperative throughout and the flight director during the landings, which had to be hand flown. During Training, pilots flew three of each maneuver in a row, with graphic feedback on their performance after each maneuver. The maneuvers were chosen to 1) replicate the V_1 cut tested in the First Study and 2) reduce any visual reference to the runway and require control in multiple axes compared to the First Study.

The results obtained with enhanced motion were different from the ones obtained in the First Study with "as is" motion. Several differences between the Motion and the No-Motion groups were found and a fairly clear picture of the effect of motion emerged. First, motion did appear to alert pilots of a disturbance faster than the visual cues alone, as stipulated in the literature based on theoretical considerations such as the time it takes for vection to develop, but only for the V_1 cut. This may be because the V_1 cut occurs close to the ground and any delay in response would result in a higher penalty than for the V_2 occurring at a higher altitude, such as scraping the wings or the tail (which did happen, but equally rarely in the two groups, and usually because of applying the wrong rudder). Due to the motion alert, the Motion group had a faster pedal response and tracked heading slightly better, but the latter only during Evaluation. The No-Motion pilots, as long as they did not have the motion cue, were unable to significantly improve their pedal-response time, even during Training when they were told what failure to expect and caught up with the motion group for heading control. Once they quasi-transferred to motion, however, they immediately caught up with the Motion group even for pedal reaction time.. So, they didn't seem to need recurrent training with motion to be able to sense and appropriately respond to motion cues.

Second, training with motion cues clearly increased the control activity of the Motion pilots, especially for wheel inputs. However, this reduced their flight precision, at least for the landing maneuvers. These performance decrements, in localizer, heading, or airspeed tracking, were in fact the largest effects found in the study, and may be operationally relevant. Most importantly, the performance deficit of the Motion group persisted even when both groups had motion at Quasi Transfer.

Perhaps the increased control activity of the Motion group was behind the curious result that for the V_2 cut at Quasi Transfer, the Motion group responded slower to the engine failure than the No-Motion group, with apparently no effect on flight precision. It may be that the Motion group was fatigued. An alternative explanation would be that both groups were equally fatigued and that the emergence of the motion cues may have had "stimulating" effect on the No-Motion group. Overall, the V_2 cut does appear to have been especially fatiguing for both groups, with several variables that had significantly improved during Training compared to Evaluation significantly deteriorating between Training and Quasi-Transfer Testing for both groups.

Third, motion affected the sidestep-landing strategy in a predictable manner. With motion, pilots landed softer. However, they also landed slightly farther from the runway threshold, but still well within the landing box. Like all effects on the landing maneuvers, this effect seems to have been consolidated during training, because it persisted even during Quasi-Transfer Testing.

Finally, both groups, regardless of motion, improved in the course of the experiment. Evaluation, however, was subject to motion effects for all four maneuvers.

These results were reflected in PF and PNF opinions. The PFs found the simulator equally acceptable compared to their company simulator regardless of group. They were also equally comfortable in it. Moreover, there was no difference between groups with respect to their comparisons of the simulator to the airplane for Control Sensitivity and Control Strategy and Technique.

There were four questions on which the two PF groups disagreed, and one of these was in favor of no motion: after Training, the No-Motion group gave the simulator higher handling-quality ratings than the Motion group gave. The ratings of the Motion group were higher than the ones of the No-Motion group for Control Feel (even at Quasi Transfer, when the No-Motion group also had motion), Other Cues (the majority of No-Motion pilots did recognize that something was amiss) and Performance (only after Evaluation).

The PNFs ratings were mostly in favor of the No-Motion group, but sometimes this was due to one of the two PNFs, while the other didn't always see a difference. They felt that the No-Motion pilots were more similar to the average pilot than the motion pilots with respect to Control Strategy and Technique (but not during Evaluation). They gave higher performance and lower workload ratings to the No-Motion pilots, except during Training. Only at Quasi Transfer, they gave better Gaining Proficiency ratings to the No-Motion pilots.

6. GENERAL DISCUSSSION AND CONCLUSIONS

This report presents the results of two studies that examined the effect of enhanced hexapod-simulator motion on recurrent evaluation in the simulator, on the course of recurrent training in the simulator, and on quasi transfer of this recurrent training to the simulator with motion as a stand-in for the airplane.

The First Study examined the effect of motion on recurrent evaluation and training of commuter airline pilots in a Level C qualified simulator of a 30-seat turboprop airplane with wing-mounted engines. The simulator motion was left "as is," i.e., as it was FAA-qualified and used round-the-clock for airline-pilot training and checking. This study revealed no systematic differences due to motion or training with motion in pilot opinions, instructor/evaluator ratings and opinions, and in extensive data collected from the simulator.

In response to this study's and a follow-up investigation's findings that lateral acceleration in the simulator may be quite attenuated in at least some simulators used for airline-pilot training and evaluation, the Second Study was conducted using a Boeing 747-400 Level D simulator with modified lateral acceleration. The gain and the phase error distortion of sway and to a lesser of heave were improved. Because of the limitations of a hexapod-platform system, however, pitch and roll and especially yaw had to be attenuated accordingly. This enhanced motion resulted in several differences and leads to the emergence of a fairly clear picture of the role motion may have in recurrent airline-pilot training and evaluation.

Enhanced hexapod motion, such as the one used in this experiment, may be required for accurate recurrent evaluation of airline pilots. This conclusion is contingent upon whether the industry perceives the effect sizes found as operationally relevant.

For recurrent training, however, no benefit of the motion provided was found. In fact, results from the landing maneuvers showed that training without motion may lower control activity and improve pilot-vehicle performance at quasi transfer to the simulator with motion compared with training in the simulator with motion. Stimulation with motion cues may induce pilots to overcorrect, while training without motion may help pilots to adopt a more steady control strategy. Because this control strategy leads to successful performance, they maintained this strategy even at quasi transfer to motion. This conclusion may be dependent on task complexity.

The differential effects of motion on the test maneuvers confirm that the effect of motion depends on the characteristics of the flying task. The importance of the quality of motion is indicated by the emergence of an early alerting effect of motion during the V_1 cut with enhanced lateral acceleration cues that was absent in the earlier study.

In conclusion, this study showed that enhanced hexapod motion, configured based on the guidelines in the literature, does have an effect. It appears to affect the accuracy of recurrent evaluation. However, the benefits for recurrent training remain questionable.

Results of this study and the previous hexapod motion research should assist the FAA in determining future research directions in the effort to develop improved motion standards. It may also contribute to finding a cost-effective solution to today's airline evaluation and training needs via an appropriate combination of fixed-base and motion-base simulators.

REFERENCES

Bjorkman, E.A. (1986). Flight Test Evaluation of Techniques to Predict Pilot Induced Oscillations. Masters Thesis, AFIT/GAE/AA/86J-1, Air Force Institute of Technology.

Boothe, E.M. (email with attached spreadsheet, October 26, 2000).

Bray, R.S. (1972). Initial Operating Experience with an Aircraft Simulator Having Extensive Lateral Motion. NASA TM X-62155.

Bürki-Cohen, J. (Ed.). (1996). Electronic Transcript of the Joint FAA/Industry Symposium on Level B Airplane Simulator Motion Requirements, Washington Dulles Airport Hilton, June 19-20. Available: http://www.volpe.dot.gov/opsad/valreqju.html

Bürki -Cohen, J., Soja, N., and Longridge, T. (1998). Simulator Platform Motion—The Need Revisited. The International Journal of Aviation Psychology, 8(3), 293-317.

Bürki-Cohen, J., Boothe, E.M., Soja N.N., DiSario, R., Go, T., and Longridge T. (2000). Simulator fidelity – The effect of platform motion. Proceedings of the International Conference on Flight Simulation: The Next Decade. Royal Aeronautical Society, London, UK.

Bürki-Cohen, J., Soja, N.N., Go, T.H., Boothe, E.M., DiSario, R., Jo, Y.J. (2001): Simulator Fidelity: The Effect of Platform Motion. Report No. DOT/FAA/RD-01/XX, unpublished manuscript.

Bürki-Cohen, J., Go, T. H., Chung, W. W., Schroeder, J. A., Jacobs, S., and Longridge, T. (2003). Simulator Fidelity Requirements for Airline-Pilot Training and Evaluation Continued: An Update on Motion Requirements Research. Proceedings of the 12th International Symposium on Aviation Psychology. Dayton, OH.

Bussolari, S. R., Young, L. R., Lee, A. T. (1987). The use of vestibular models for design and evaluation of flight simulator motion. Paper presented at the Aerospace Medical Panel Symposium on Motion Cues in Flight Simulation and Simulator Induced Sickness, Brussels, Belgium, September.

Federal Aviation Administration (1991). Airplane Simulator Qualification. Advisory Circular No. 120-40B, U.S. Department of Transportation, Washington, DC.

Federal Aviation Administration (2001). Airline Transport Pilot and Aircraft Type Rating: Practical Test Standards for Airplane. FAA-S-8081-5D with change 1. Flight Standards Service. U.S. Department of Transportation, Washington, DC.

Go, T. H., Bürki-Cohen, J., and Soja, N.N. (2000). The effect of simulator motion on pilot training and evaluation (AIAA 2000-4296). American Institute of Aeronautics and Astronautics.

Go, T. H., Bürki-Cohen, J., Chung, W. W., Schroeder, J. A., Saillant, G., Jacobs, S., and Longridge, T. (2003). The Effects of Enhanced Hexapod Motion on Airline-Pilot Recurrent Training and Evaluation (AIAA 2003-5678). American Institute of Aeronautics and Astronautics.

Guedry, F.E. (1968). Conflicting sensory orientation cues as a factor in motion sickness. Paper presented at the Fourth Symposium on the Role of the Vestibular Organs in Space Exploration, Naval Aerospace Medical Institute, Pensacola, FL.

Gundry, J. (1976). Man and motion cues. Paper presented at the Third Flight Simulation Symposium, London, UK.

Hall, J.R. (1978). Motion versus visual cues in piloted flight simulation (AGARD CP-249). Paper presented at the Flight Mechanics Panel Specialists Meeting on Piloted Aircraft Environment Simulation Techniques, Brussels, Belgium.

Hall, J.R. (1989). The Need for Platform Motion in Modern Piloted Flight Training Simulators (Technical Memorandum FM 35). Royal Aerospace Establishment, London, UK.

Hess, R. A. (1989). Theory for Aircraft Handling Qualities Based on a Structural Pilot Model. Journal of Guidance, Control, and Dynamics, 12(6), 792-797.

Homans, G. C. (1958). Group Factors in Worker Productivity. In E. Maccoby, T. Newcombs, and E. Hartley (Eds.), Readings in Social Psychology, New York: Holt.

Hosman, R. (1999). Are Criteria for Motion Cueing and Time Delays Possible? (AIAA 99-4028). American Institute of Aeronautics and Astronautics.

Hosman, R.J.A.W. and van der Vaart, J.C. (1981). Effects of vestibular and visual motion perception on task performance. Acta Psychologica, 48, 271-287.

Lahiri, A. (2000). Significance of a qualitative handling assessment approach towards motion system requirements for flight simulators. Proceedings of the International Conference on Flight Simulation - A Decade of Regulatory Change: Has the Situation Changed for the Better? Royal Aeronautical Society, London, UK.

Levison, W. H. (1981). Effects of whole-body motion simulation on flight skill development (Final Report AFOSR-TR-82-006). Bolling Air Force Base, Air Force Office of Scientific Research, Washington, DC.

Longridge, T., Ray, P., Boothe, E., and Bürki-Cohen, J. (1996). Initiative towards more affordable flight simulators for U.S. commuter airline training. Proceedings of the International Conference on Training - Lowering the Cost, Maintaining the Fidelity. Royal Aeronautical Society, London, UK.

Meiry, J.L. (1966). The Vestibular System and Human Dynamic Space Orientation. NASA CR-628, 1966.

Mikula, J., Chung, W, and Tran, D. (1999). Motion Fidelity Criteria for Roll-Lateral Translational Tasks (AIAA 99-4329). American Institute of Aeronautics and Astronautics.

Mulder, M., Chiecchio, J., Pritchett, A., and van Paassen, M. (2003). Testing Tunnel-in-the-Sky Displays and Flight Control Systems With and Without Flight Simulator Motion. Proceedings of the 12th International Symposium on Aviation Psychology. Dayton, OH.

Oman, C. (1991). Sensory conflict in motion sickness: An observer theory approach. In S. R. Ellis, M. K. Kaiser, & A. C. Grunwald (Eds.), Pictorial communication in virtual and real environments (pp. 362-376). New York: Taylor and Francis.

Reid, L. D., & Nahon, M. A. (1988). Response of airline pilots to variations in flight simulator motion algorithms. Journal of Aircraft, 25(7), 639-646.

Roscoe, S. N. (1991). Simulator qualification: Just as phony as it can be. The International Journal of Aviation Psychology, 1(4), 335-339.

Scanlon, C. H. (1987). Effect of Motion Cues During Complex Curved Approach and Landing Tasks. NASA TP-2773.

Sinacori, J.B. (1977). The Determination of Some Requirements for a Helicopter Flight Research Simulation Facility. NASA CR-152066.

Schroeder, J.A. (1999) Helicopter Flight Simulator Motion Platform Requirements. NASA TP-208766.

Schroeder, J., Chung, W., Tran, D., Laforce, S. (1998). Pilot-induced oscillation prediction with three levels of simulation motion displacement (AIAA 98-4333). American Institute of Aeronautics and Astronautics.

Waag, W.L. (1981). Training Effectiveness of Visual and Motion Simulation (Report AFHRL-TR-79-72). Airforce Human Resource Laboratory, Brooks Air Force Base, Texas.

White, A. D. (1994). The impact of cue fidelity on pilot behaviour and performance. Bedford, United Kingdom: FDS Department, Defence Research Agency.

Young, L. R. (1978). Visually Induced Motion in Flight Simulation. AGARD CP-249, pp. 16-1-16-8.

Zaichik, L. E., Rodchenko, V. V., Rufov, I. V., Yashin, Y. P., White, A. D. (1999). Acceleration perception (AIAA 99-4334). American Institute of Aeronautics and Astronautics.

APPENDIX 1. FIRST STUDY RESULTS

A1.1. Resolution (power)

Table A1-1 summarizes the Group and Phase effect sizes (defined as the minimum difference between the standardized means that will lead to the rejection of the null hypothesis with a probability of .80) of several important variables for the analyses done here.

Maneuver	Measure	Effect Size	
		Group	Phase
V_1 Cut	STD bank	.67 deg	.78 deg
	STD HDG deviation	.64 deg	.74 deg
	Pedal RT (s)	.70 s	.81 s
RTO	RMS lateral deviation	6.10 ft	7.58 ft
	STD HDG deviation	.84 deg	1.05 deg
	Power lever RT (s)	.43 s	.54 s

Table A1-1. First Study Detectable Group and Phase Effects

A1.2. V_1 Cut Pilot-Vehicle Performance and Pilot Behavior

For this maneuver, the dependent variables used in the MANOVA are listed below (18 variables). For a discussion of the results in comparison with the results of the Second Study, see 5.3.3.5.

Performance

- STD and average failure-induced heading deviation (average of heading deviation in the direction of the failed engine)
- STD bank angle and average failure induced bank angle (average of bank angle in the direction of the failed engine)
- STD pitch angle
- Average airspeed exceedance (average of airspeed exceeding the ±5 knots about the desired airspeed)

Behavior

- Roll and yaw activities (average of absolute roll and yaw rates)
- Pedal reaction time
- Root mean square (RMS) and number of reversals of column, wheel, and pedal responses

- Response bandwidth of the column, wheel, and pedal actions (frequency below which the corresponding power spectral density curves are .5 of total area)

MANOVA results for Group and Phase effects

- Marginally significant Group effect: Wilks' Lambda Λ=.745, F(18,89)=1.69, p=.06
- Highly significant Phase effect: Λ=.50, F(36,178)=2.04, p=.001
- No Group and Phase interaction: Λ=.72, F(36,178)=.87, p=.68

Variable	Mean		Statistics	
	Motion	No-motion	F(1,106)	p
Wheel reversals	3.00	3.58	4.23	.04
Wheel BW (Hz)	.12	.09	6.03	.02
Pedal reversals	1.50	1.08	10.17	.002

Table A1-2. First Study V_1 Cut Group Differences (Marginal)

Variable	Mean	Differences			Statistics	
		I-II	II-III	I-III	F(2,106)	p
Failure-induced bank (deg)	3.12	.40	1.26*	1.66*	11.62	<.0001
STD pitch (deg)	4.18	.29	.73*	1.02*	10.48	<.0001
Roll activity (deg/s)	3.90	.21	.50	.71*	3.26	.04
RMS pedal (in)	.80	.06	.10	.16*	3.79	.03

* indicates significant difference (p<.05)

Table A1-3. First Study V_1 Phase Differences (I=Evaluation, II=Training, III=Quasi –Transfer Testing)

V_1 Cut Summary

The finding of no difference between Motion and No-Motion group in pedal reaction time indicated that the motion of the test simulator did not provide the alerting function to the pilots. The motion cues in this case only affected pilots' lateral-directional control activities as indicated by differences in wheel reversals and bandwidth as well as pedal reversals between the groups. Regardless of Group, general improvement was observed on bank and pitch performance as well as reduction in lateral-directional control activities at Quasi Transfer.

A1.3. Rejected Takeoff (RTO) Pilot-Vehicle Performance and Pilot Behavior

The dependent variables used in the MANOVA for RTO are as follows (8 variables):

Performance

- STD and maximum heading deviation
- RMS lateral deviation (from runway centerline)

Behavior
- Yaw activities (average of absolute roll and yaw rates)
- Power lever reaction time (the duration from the time when the failed engine torque reduces to 80% of its full power to the time when the torque of the good engine has been reduced to 80%)
- Root mean square (RMS) and number of reversals of pedal responses
- Pedal response bandwidth

MANOVA results for Group and Phase effects
- No Group effect: Wilks' Lambda Λ=.89, F(8,81)=1.28, p=.27
- Highly significant Phase effect: Λ=.62, F(16,162)=2.74, p=.0006
- No Group and Phase interaction: Λ=.80, F(16,161)=1.21, p=.27

Variable	**Mean**	**Differences**			**Stats**	
		I-II	**II-III**	**I-III**	**F(2,88)**	**p**
Max heading (deg)	7.56	1.56	1.84*	3.40*	9.85	.0001
RMS pedal (in)	.98	.13	.26	.39*	5.01	.009
Pedal BW (Hz)	.06	-.01	-.05*	-.07*	7.19	.001

* indicates significant difference (p<.05)

Table A1-4. RTO Results for Phase (I=Evaluation, II=Training, III=Quasi-Transfer Testing)

RTO Summary
The motion cues did not have any effects on RTO, as no differences between groups were found for any of the variables. This result might be driven by the fact that in the RTO maneuver, the airplane was always on the ground, and hence the pilots relied more on runway visual cues than motion cues. Regardless of Group, improvement was observed during Quasi-Transfer Testing on heading performance, and this seemed to be achieved by using a different control strategy (lower pedal RMS but higher bandwidth).

A1.4. Individual Training Progress[5]

The individual training progress was examined by looking at the difference in the percentage of pilots that improved from First (Evaluation) to Last Training, Last Training to Quasi-Transfer Testing, and from First Training to Quasi-Transfer Testing. Variables examined were related to PF control performance (pedal reaction time, STD heading, and STD bank for V_1 cut; power lever reaction time, STD heading, and RMS lateral deviation for RTO) and control activities (RMS wheel and RMS pedal). A greater than 15% reduction in the value of a variable from one level of the experiment to the later one was considered an improvement. Fisher's Exact test was then used to examine whether the difference in the percentages of improved pilots between groups was significant. The summary of the results for V_1 cut and RTO is shown in Table A1-5 and Table A1-6.

Variable	1st to Last Training			1st Training to QT			Last Training to QT		
	% Improved		Fisher's Exact p	% Improved		Fisher's Exact p	% Improved		Fisher's Exact p
	Mot	No-Mot		Mot	No-Mot		Mot	No-Mot	
Pedal RT	22.2	36.8	.27	20.0	31.3	.38	25.0	27.8	.58
STD heading	27.8	26.3	.60	33.3	43.8	.41	18.8	50.0	.06
STD bank	27.8	15.8	.31	40.0	62.5	.19	50.0	50.0	.63
RMS Wheel	16.7	10.5	.47	26.7	43.8	.27	12.5	11.1	.74
RMS Pedal	27.8	5.3	.08	53.3	81.3	>.1	43.8	83.3	.02

Table A1-5 Fisher's Exact Statistics of Group Differences in Percentage Improvement Among First Training, Last Training, and Quasi-Transfer Testing for V_1 Cut

Variable	1st to Last Training			1st Training to QT			Last Training to QT		
	% Improved		Fisher's Exact p	% Improved		Fisher's Exact p	% Improved		Fisher's Exact p
	Mot	No-Mot		Mot	No-Mot		Mot	No-Mot	
Power lever RT	46.7	38.5	.48	40.0	40.0	.66	25.0	23.1	.63
STD heading	53.3	38.5	.34	60.0	50.0	.47	25.0	38.5	.35
RMS lateral deviation	53.3	38.5	.34	60.0	50.0	.47	37.5	23.1	.34
RMS Wheel	26.7	15.4	.40	26.7	40.0	.39	12.5	38.5	.12
RMS Pedal	40.0	46.2	.52	53.3	80.0	.18	43.8	53.8	.43

Table A1-6. Fisher's Exact Statistics of Group Differences in Percentage Improvement Among First Training, Last Training, and Quasi-Transfer Testing for RTO

[5] Unlike in Second Study, the number of training runs was not equal among the pilots in the First Study as they needed only to reach the company standard (I/E grade of 3) to end the training. Comparisons for improvement were therefore done differently than in the Second Study.

A1.5. Comparison of Failure-Induced Lateral Acceleration of Several Simulators

Simulator	Aircraft Weight (lbs)	Engine Type	Engine Failure Speed (kts)	Failed Engine Power Decay Time (s)	Maximum Failure-Induced Lateral Acceleration from EOM at cg (g)	Maximum Failure-Induced Lateral Acceleration from motion drive equations at pilot station (g)
B737-200	99330	Turbofan	135	7.6	0.078	
B737-800	151699	Turbofan	129	8.9	0.062	
A-320#1	141975	Turbofan	131	14.3	0.04	0.04
B747-400	626400	Turbofan	125	7.0	0.071	0.070
B737-300*		Turbofan	118		0.062	0.047
A-330-300*		Turbofan	135		0.065	0.059
B757*		Turbofan	120		0.002	0.003
SAAB 340*		Turboprop	117		0.078	0.025
Test sim (auto test)	17893	Turboprop	84	1.2	0.1	0.06
Test sim (from experiment)#	20500	Turboprop	110	1.2	0.21	0.069

*From initial analysis only (Boothe, 2000).
#For this comparison, a V_1 cut maneuver with grade 3 is used.
Note: Blank cells on the table indicate the data are not available.

Table A1-7. V_1 Cut Lateral Acceleration Data from Several Simulators

As can be seen from ??, the values of the maximum failure-induced lateral acceleration from the equations of motion at cg as obtained from the automatic testing, mostly fell within .04 and .1 g. An exception is the value reported for the B757 simulator, which was unusually low (.002 g). Unfortunately, this information could not be studied further due to the data loss. The values of the maximum failure-induced lateral acceleration from the equations of motion of the test simulator obtained in the experiment were in general higher than the values from the automatic testing (.2 to .3 g). The values of the failure-induced lateral acceleration from the motion drive equations were in general about the same or lower than the respective values from the equations of motion. With the exception of the B757 simulator, these values ranged from .025 to .07 g. Again, the value of the lateral acceleration from the motion drive equations of the B757 simulator was unusually low. The discrepancy between the maximum failure-induced acceleration from the equations of motion and from the motion drive equations was relatively large for the Saab 340 simulator and the test simulator.

A1.6. Instructor/Evaluator Grades

A set of fourteen I/Es tested between one and nine crews and provided grades after each maneuver. To control bias, they were counterbalanced across motion conditions and were unaware of the purpose of the experiment. The simulator displays indicated that the motion was on and the motion was washed out only after initialization. The grades ranged between 1 (unsatisfactory) and 4 (excellent). Grades of 2 and 3 meant that the crew satisfied the PTS or company standards, respectively.

The I/E grades were examined in many different ways, for Group effects during the different phases, for differences in Group improvement between phases, for differences in percentages of crews improved, for differences between the number of crews receiving (extremely) low vs. high grades, etc. (see Bürki-Cohen et al., 2001, for details). Only one of these analyses found a statistically significant difference in grades due to the motion variable. Figure A1- shows the percentage of grades in each grading category as a function of maneuver, trial, and Motion group during Evaluation and Quasi-Transfer Testing. The I/Es did perceive differences in the performance of the V_1 cut during Quasi-Transfer Testing, when both groups had motion: They gave more grades of 1 to the crews trained without motion (N = 32, Fisher Exact p=.05). The groups received an equal number of grades of 3 and neither group received any grades of 4, so the difference was all in the number of grades of 1 and 2.

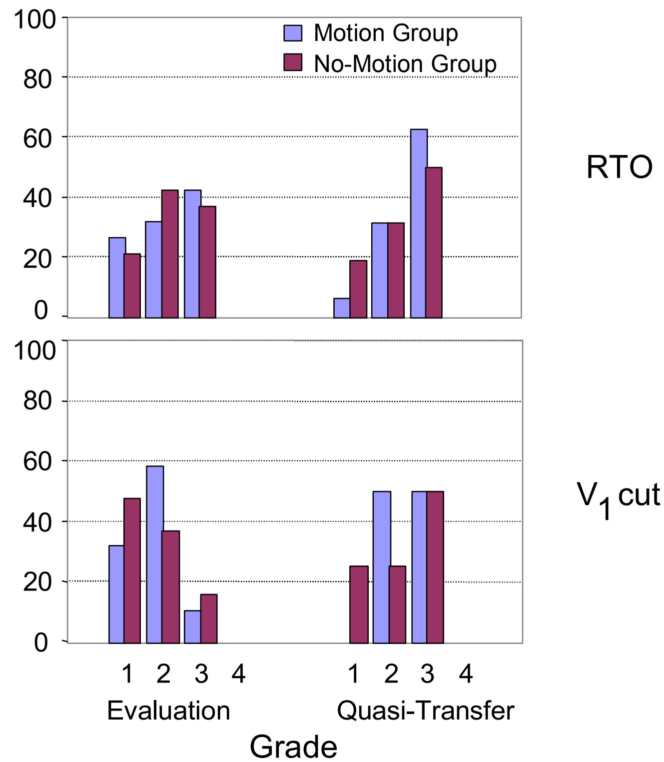
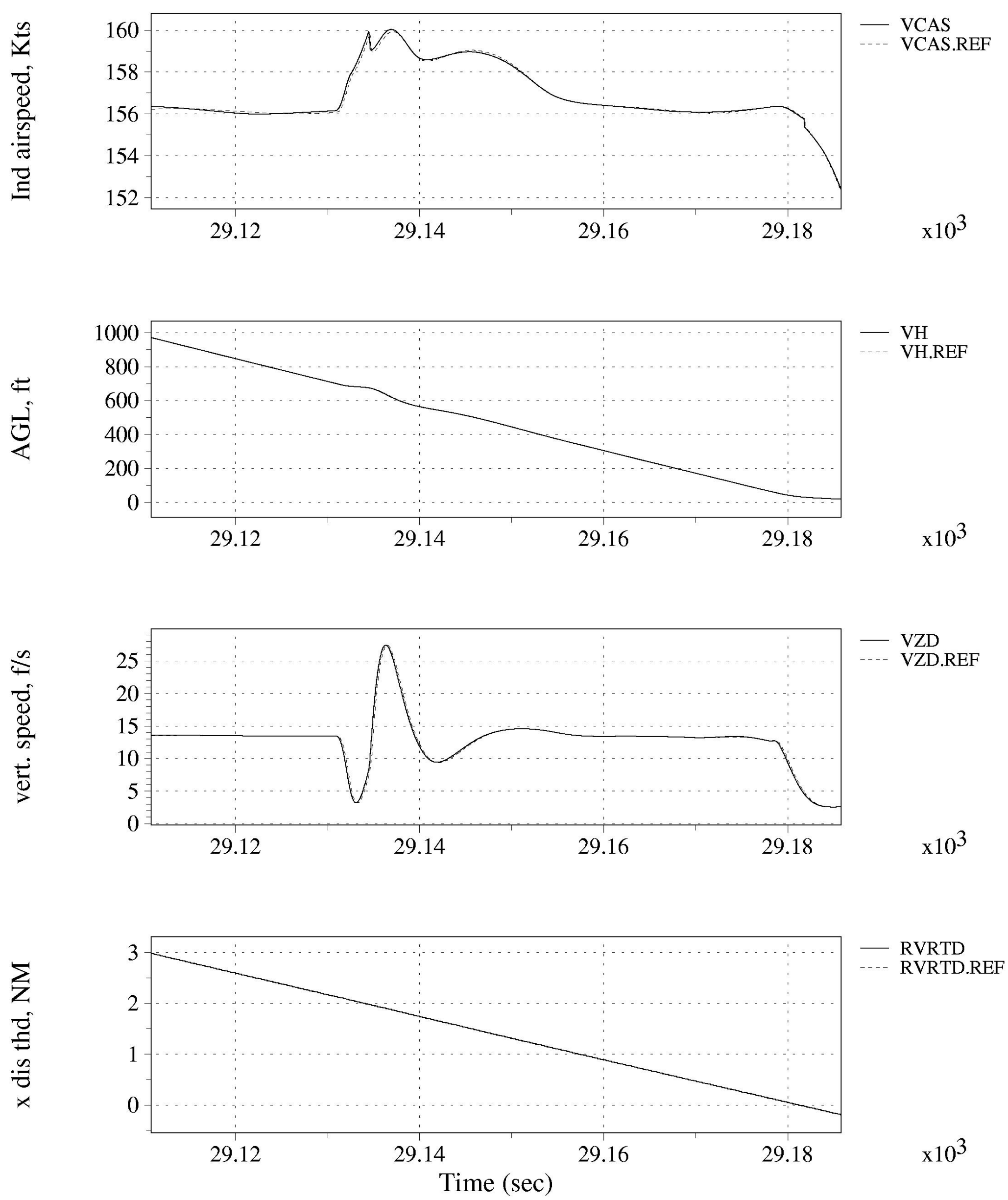


Figure A1-. First Study Percentage of Grades in Each Grading Category as a Function of Maneuver, Phase, and Group

APPENDIX 2. SAMPLE DAILY CALIBRATION TEST

Daily Check



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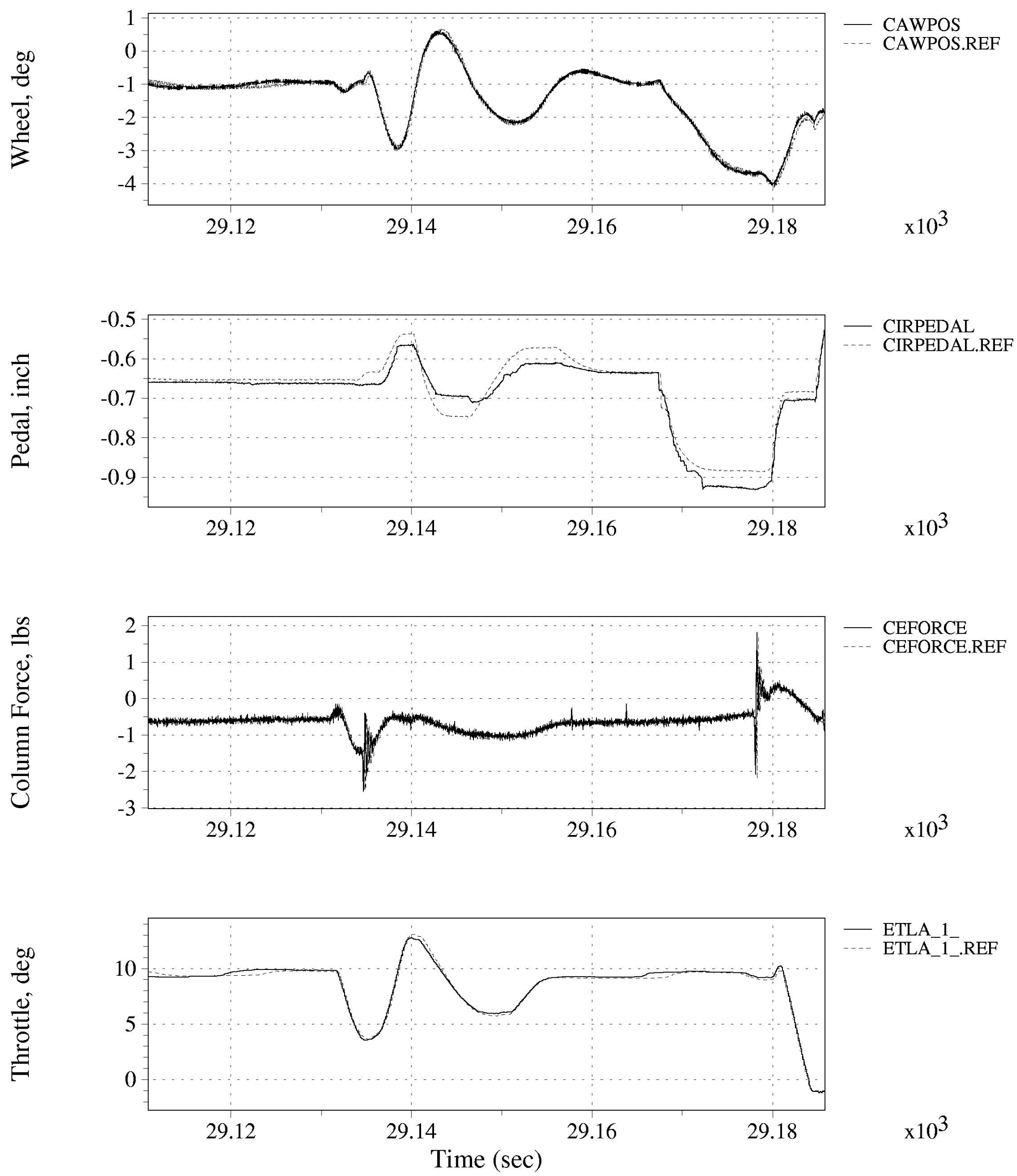
Daily Check

Daily Check



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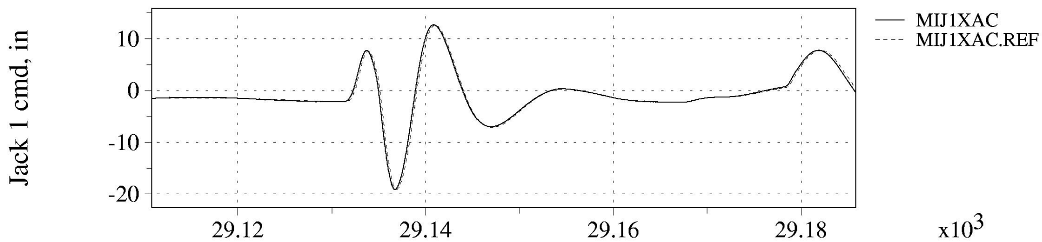

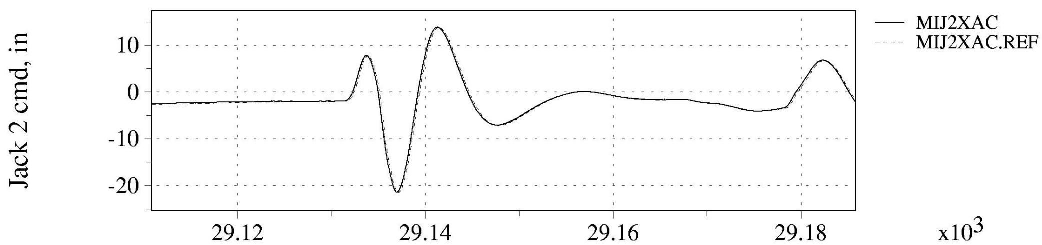

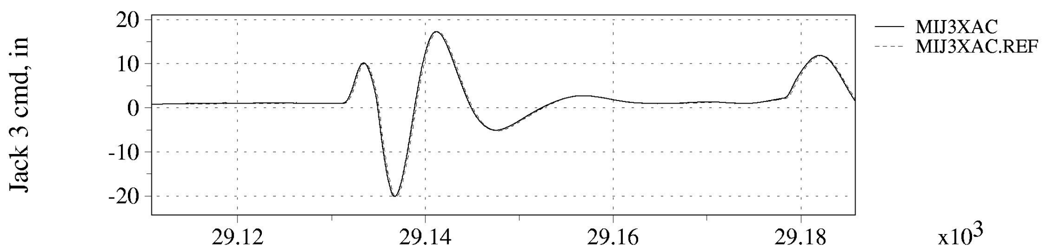

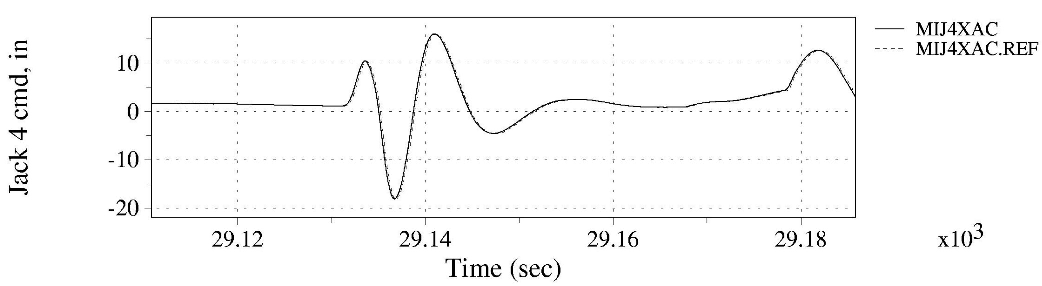

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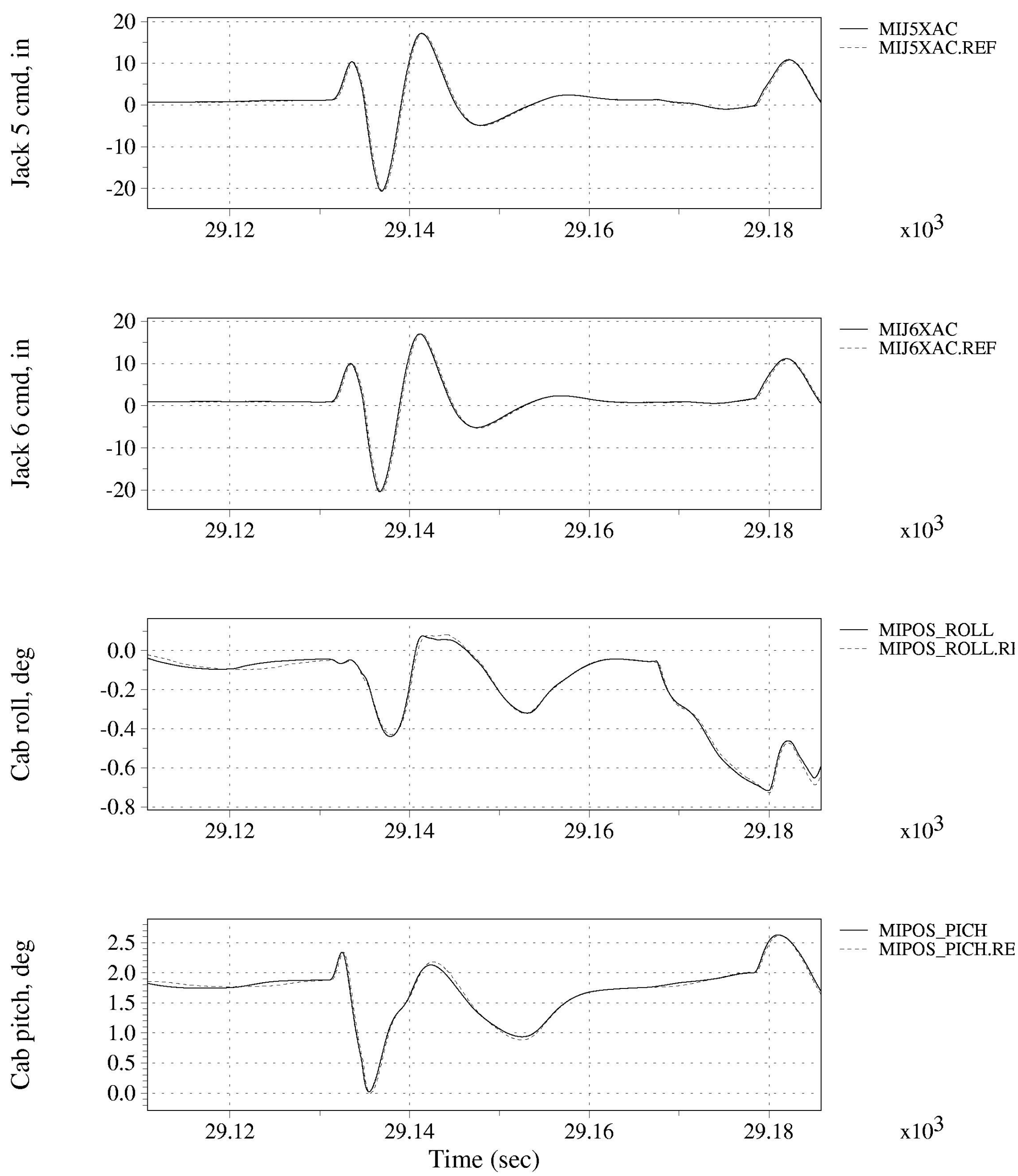

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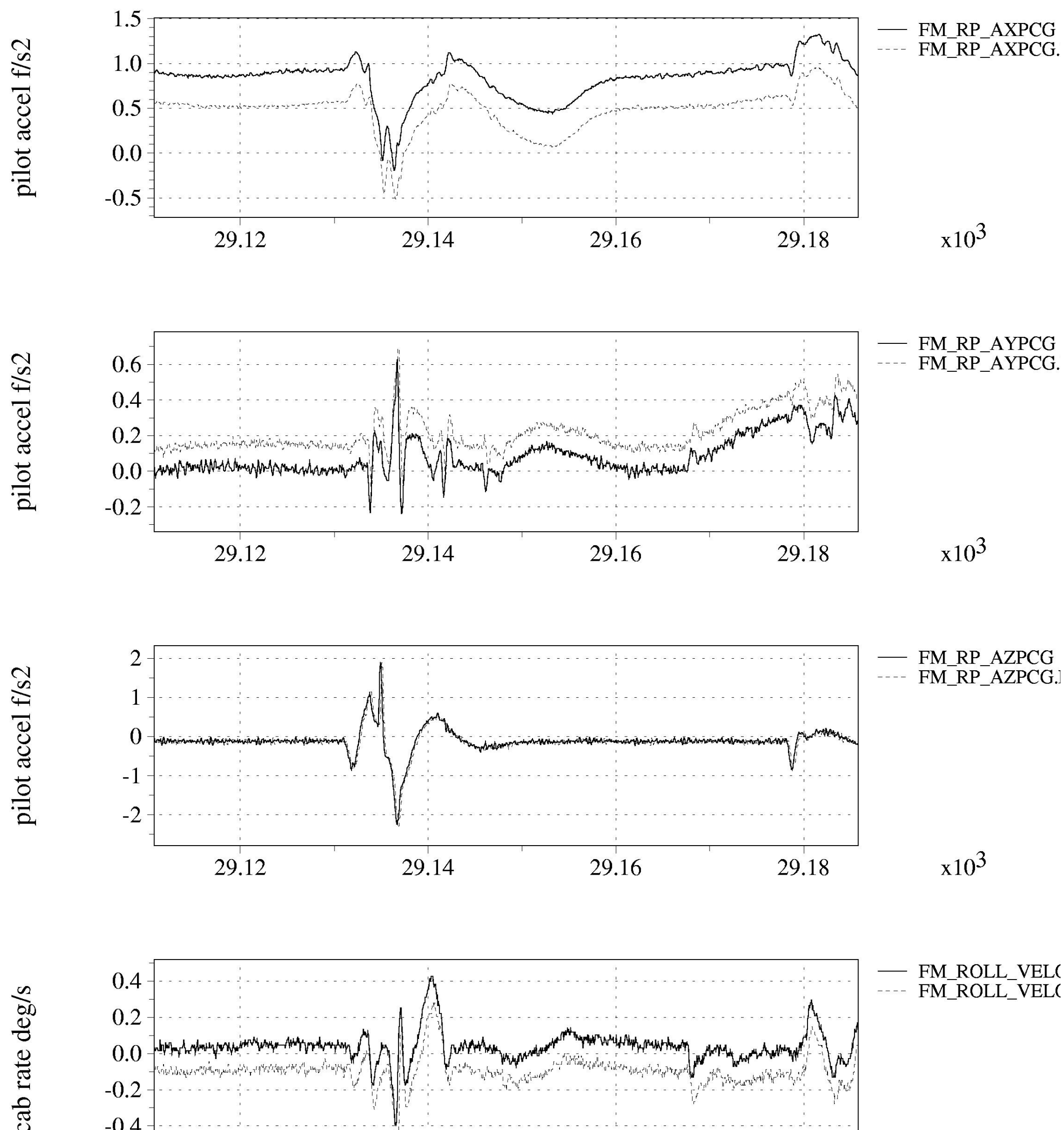

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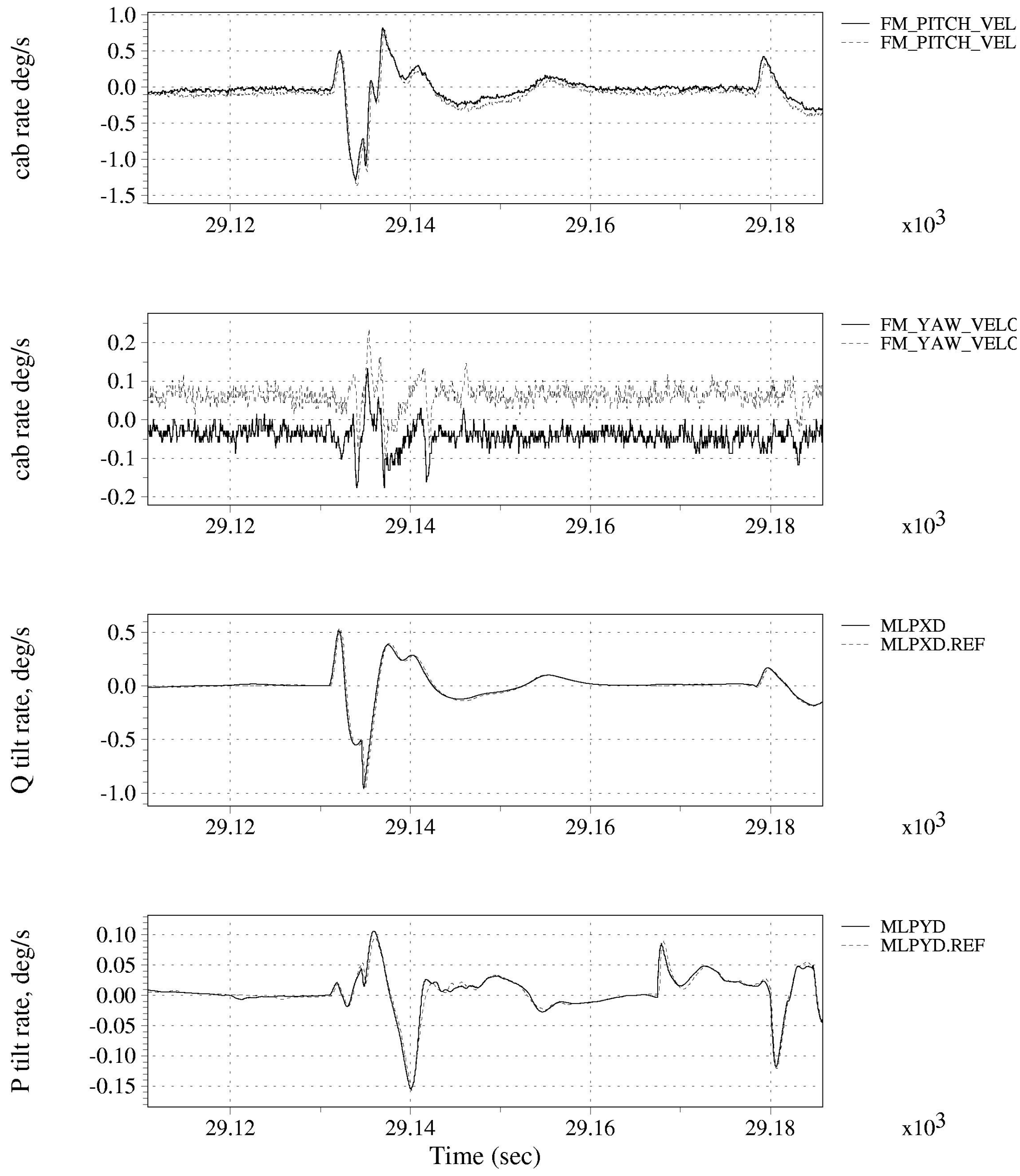

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APPENDIX 3. BRIEFING OF PILOT FLYING

PILOT BRIEFING

What is this all about?

Simulators have become indispensable for safe and effective pilot training and evaluation. You will be helping us to design simulators that will best serve that purpose.
U.S. DOT Volpe Center, NASA Ames Research Center, and FAA have jointly determined the test plan. We have made every effort to design an experiment that will lead to improved simulator training and evaluation for all pilots.

What are we asking you to do?

Flying

You will be asked to fly challenging scenarios in the simulator. We rely on you to fly as precisely as possible. For example, no matter how difficult a departure or a landing maneuver is, you should try to align the flight path with the runway centerline as accurately as possible. You will be given a chance to practice the maneuvers with graphical feedback on the precision of your flight path. It is critical that you make any effort to improve your performance based on the feedback. The best performers before and after practice will receive an award after completion of the experiment. But remember, you are an experienced pilot, and your ability to perform well (or not so well) reflects on the simulator, not on your performance on the line.
Please note that you are the Pilot Flying and have *total responsibility and command of the aircraft*. Your non-flying pilot is not familiar with your airline's procedures, so just command what you wish and he will execute that command.

Questionnaires

After each flying phase, you will be filling out a questionnaire. Your opinions are critical in improving the simulator. We will ask some questions over and over again--please answer them based on the maneuvers you have flown since the last questionnaire. Feel free to add any comments. At the end, you will be given chance to give us additional feedback.
Please reserve all comments for the questionnaires, so that your opinions are documented. Do not discuss them with the Pilot Not Flying or the technicians.

Sequence

Morning
Briefing (30 min)
Phase I: Flying & Questionnaires (1.5 hrs)
Break with refreshments (30 min)
Phase II: Flying w/ feedback, Quest. (2.5 hrs)

Afternoon
Lunch (1 hr 15 min)
Phase III: Flying & Questionnaires (2 hrs)
Debriefing

Need for Discretion

To draw valid conclusions from this experiment, it is **critical** that all participants are fresh to the experiment without expectations or preconceived opinions. Thus, please encourage your colleagues to participate, but don't discuss your experience with them. We will provide you with a full report after the conclusion of the experiment.

LOCAL AREA FLIGHT PLAN FOR NASA 123

This is a training flight remaining in the DFW area.
Weather and equipment are legal for takeoff and landing.
All takeoffs are to use maximum thrust.
NOTAM: ILS 36R inoperative.

Airport, Weather, and Aircraft Information

For takeoff

Dallas Forth Worth Airport, TX

Runway	36 R
Runway Length	11,388 feet
Elevation	575 feet MSL
Time of Day	Day

Weather

Ceiling	600 feet
Visibility	RVR 600/600/600
Temperature	15 °C
Wind	175° at 10 knots
Altimeter Setting	29.92
Takeoff Alternate	DEN

Airplane

Inoperative Systems	Autothrottle
Takeoff Weight	550,000 pounds
Zero Fuel Weight	490,000 pounds
Center of Gravity	22% Mac
Flap Setting	10
V_1	121 KIAS
V_R	129 KIAS
V_2	150 KIAS

APPENDIX 4. AIR-TRAFFIC-CONTROL SCRIPT

EVALUATION & TRANSFER TESTING PHASES: SCENARIO 1

Scen_1 FAA Motion Vr Cut #1 Land 36L **Scenario 111 Button 2**

Aircraft positioned on DFW Runway 36R and configured for takeoff with 10° Flaps. No Autothrottles.

DFW Twr	124.15
REGIONAL DEP	118.55
REGIONAL APP	118.42

Dept ATIS **"Tango"**

TANGO (T.O. R36R V1 and VR cuts)

> Dallas Ft. Worth International departure information TANGO, 1750 Zulu weather, Winds 170 at 10, visibility one quarter mile fog, ceiling 500 overcast, temperature 15, dewpoint 13, altimeter 29.92. Runway 36 Right in use. Advise you have information TANGO.

Twr Freq: **124.15**

DFW Tower: *Nasa 123, after departure, maintain runway heading, climb and 3,500, wind 170 degrees at 10, runway 36R, cleared for takeoff.*

After VR & 20 feet AGL # 1 engine failure (flameout..... later a loss of oil, to preclude a restart)

Runway heading, during engine shutdown and aircraft cleanup, to maintain 3,500 feet MSL.

Pilot will notify DFW Tower of engine problem. (Confederate pilot will ensure no engine restart).

DFW Tower: *Nasa 123, roger, continue on runway heading, maintain 3,500, contact departure on 118.55*

After Nasa123 contacts departure control, vector the flight, left turn to west (270 degrees) for about 5 NM from DFW for approach to 36L.

Regional DEP: *Nasa 123, departure, radar contact, maintain 3,500, pilots discretion turn left heading 270 for vector to ILS runway 36L final approach course.*

Pilot will then acknowledge instructions.

Regional DEP gives weather update

Regional DEP: *Nasa 123, new DFW weather, visibility 1 mile, fog, ceiling 500 overcast, altimeter 29.92.*

Vector the flight, left turn to south (180 degrees) on downwind leg, about 5 NM abeam DFW.

Regional DEP: *Nasa 123, turn left heading 180, contact Approach on 118.42.*

Pilot contacts approach control and approach control acknowledges.

At a point abeam the airport on downwind:

Regional APP: *Nasa 123, descend and maintain 2,500. Verify you have Information Lima.*

LIMA (Land R36L, after VR cut)

DFW Twr	124.15
REGIONAL DEP	118.55
REGIONAL APP	118.42

Dallas Ft. Worth International arrival information LIMA, 1810 Zulu weather, Wind 220 at 10, visibility one mile fog, ceiling 500 overcast, temperature 15, dewpoint 13, altimeter 29.92. Runway 36 Left and runway 36 Right in use. Advise you have information LIMA.

When flight abeam CHARR, vector the flight, left turn to east (090 degrees).
DFW Tower gives latest RVR: Runway 36L RVR 5200 Feet

Regional APP: *Nasa 123, turn left heading 090, Runway 36L RVR 5,200*

2 1/2 NM from LOC intercept, vector the flight, left turn to 020 degrees, cleared ILS 36L.

Regional APP: *Nasa 123, 6 miles from BOBIN, turn left heading 020, maintain 2,500 until established on the localizer, cleared ILS Runway 36L Approach.*

Disconnect Autopilot when wings level and before localizer capture.

At BOBIN, disconnect flight directors. (Raw Data Approach with GS out minimums of MDA 1020¹ (432¹ AGL) and RVR 5200 or 1-mile visibility).

At BOBIN or when established on localizer switch to Tower Freq

ILS/DME Rwy 36**L**	354°	111.9
IBXN		

Regional APP: *Nasa 123, contact tower on 124.15*

DFW Tower: *Nasa 123, Wind 220 degrees at 10, Runway 36L RVR 5,200, cleared to land Runway 36L.*

After landing:

DFW Tower: *Nasa 123, after landing roll, stop on the runway.*

FREEZE SIMULATOR WHEN A/C COMES TO A FULL STOP

EVALUATION & TRANSFER TESTING PHASES: SCENARIO 2

Scen_2 FAA Motion V1 Cut #4 S/S Land 36R Scenario 121 Button 3

Aircraft positioned on DFW Runway 36R and configured for takeoff with 10° Flaps. No Autothrottles.

DFW Twr	124.15
REGIONAL DEP	118.55
REGIONAL APP	118.42

Dept ATIS **"Tango"**

TANGO (T.O. R36R V1 and VR cuts)

Dallas Ft. Worth International departure information TANGO, 1750 Zulu weather, Wind 170 at 10, visibility one quarter mile fog, ceiling 500 overcast, temperature 15, dewpoint 13, altimeter 29.92. Runway 36 Right in use. Advise you have information TANGO.

Twr Freq: **124.15**

DFW clears NASA 123 for takeoff.

DFW Tower: *Nasa 123, after departure, maintain runway heading, climb and maintain 3,500, wind 170 degrees at 10, Runway 36R, cleared for takeoff.*

After V1 # 4 engine failure (flameout..... later a loss of oil, to preclude a restart)

Runway heading, during engine shutdown and aircraft cleanup, to maintain 3,500 feet MSL.

Pilot will notify DFW Tower of engine problem. (Confederate pilot will ensure no engine restart).

DFW Tower: *Nasa 123, roger, continue on runway heading, maintain 3,500, contact departure on 118.55*

After Nasa123 contacts departure control, vector the flight, left turn to west (270 degrees) for about 5 NM from DFW for approach to 36L.

Regional DEP: *Nasa 123, departure, radar contact, maintain 3,500, pilots discretion turn left heading 270 for vector to ILS runway 36L final approach course.*

Pilot will then acknowledge instructions.

Regional DEP gives weather update

Regional DEP: *Nasa 123, new DFW weather, visibility 5, mist, ceiling 1,100 overcast, altimeter 29.92.*

Vector the flight, left turn to south (180 degrees) on downwind leg, about 5 NM abeam DFW.

Regional DEP: *Nasa 123, turn left heading 180, contact Approach on 118.42.*

Pilot contacts approach control and approach control acknowledges.

At a point abeam the airport on downwind.

DFW Twr	124.15
REGIONAL DEP	118.55
REGIONAL APP	118.42

Regional APP: *Nasa 123, descend and maintain 2,500, expect ILS Runway 36L Approach, sidestep to Runway 36R. Verify you have Information Mike.*

ILS/DME Rwy 36**L**	354°	111.9
IBXN		

b

MIKE (Land R36 L or R36R)

Dallas Ft. Worth International arrival information MIKE, 1810 Zulu weather, Wind 310 at 10, visibility five mile, ceiling 1100 overcast, temperature 15, dewpoint 13, altimeter 29.92. Runway 36 Left and runway 36 Right in use. Advise you have information MIKE.

When flight abeam CHARR, vector the flight, left turn to east (090 degrees).

Regional APP: *Nasa 123, turn left heading 090.*

2 1/2 NM from LOC intercept, vector the flight, left turn to 020 degrees, cleared ILS 36L.

Regional APP: *Nasa 123, six miles from BOBIN, turn left heading 020, maintain 2,500 until established on the localizer, cleared for ILS Runway 36L Approach, sidestep Runway 36R.*

Disconnect Autopilot when wings level and before localizer capture.

At BOBIN, disconnect flight directors. (Raw Data Approach with GS out minimums of MDA 1020' (432' AGL) and RVR 5000 or 1-mile visibility).

When Nasa 123 is established on the localizer.

Regional APP: *Nasa 123 contact DFW tower on 124.15.*

After Nasa 123 contacts DFW tower.

DFW Tower: *Nasa 123, report Runway 36R in sight.*

When Nasa 123 reports Runway 36R in sight.

DFW Tower: *Nasa 123, wind 310 degrees at 10, cleared to land Runway 36R.*

After landing:

DFW Tower: *Nasa 123, after landing roll, stop on the runway.*

FREEZE SIMULATOR WHEN A/C COMES TO A FULL STOP

TRAINING PHASE: MANEUVER 1

m1(scen_1) FAA Motion Vr Cut #4 T/O Only Scenario 211 Button 5

Aircraft positioned on DFW Runway 36R and configured for takeoff with 10° Flaps and no Autothrottles.

DFW Twr	124.15
REGIONAL DEP	118.55
REGIONAL APP	118.42

Dept ATIS **"Tango"**

TANGO (T.O. R36R V1 and VR cuts)

Dallas Ft. Worth International departure information TANGO, 1750 Zulu weather, Wind 170 at 10, visibility one quarter mile fog, ceiling 500 overcast, temperature 15, dewpoint 13, altimeter 29.92. Runway 36 Right in use. Advise you have information TANGO.

Twr Freq: **124.15**

DFW Tower: *Nasa 123, after departure, maintain runway heading, climb and 3,500, wind 170 degrees at 10, Runway 36R, cleared for takeoff.*

After VR & 20 feet AGL # 4 engine failure (flameout)

Runway heading, during engine shutdown and aircraft cleanup commencing at 800¹ AGL.

SIMULATOR WILL FREEZE AT 2000 FEET MSL.

TRAINING PHASE: MANEUVER 2

m2(scen_1) FAA E4 36L (Land Only) **Scenario 212 Button 9**

Aircraft positioned outside of CHARR heading 020º to intercept the ILS 36L Localizer, with #4 Engine shutdown, no Autothrottles, Autopilots on for approximately 15 seconds until aircraft stabilizes then OFF and Flight Directors OFF at BOBIN (OM).

Arr ATIS **"Echo"**

ECHO (Land R36 L, #4 eng cut)

DFW Twr	124.15
REGIONAL DEP	118.55
REGIONAL APP	118.42

Dallas Ft. Worth International arrival information ECHO, 1810 Zulu weather, Wind 130 at 10, visibility one mile fog, ceiling 500 overcast, temperature 15, dewpoint 13, altimeter 29.92. Runway 36 Left and runway 36 Right in use. Advise you have information ECHO.

APP Freq: **118.42**

Regional APP: *Nasa 123, continue heading 020, maintain 2500 until established on the localizer, cleared for ILS 36L Approach. Runway 36L RVR 5,200.*

Approaching Outer Marker:

ILS/DME Rwy 36**L** 354º 111.9
IBXN

Regional APP: *Nasa123, Contact Tower on 124.15*

DFW Tower: *Nasa 123, wind 130 degrees at 10, cleared to land Runway 36L.*

DFW Tower: *Nasa 123, after landing roll, stop on the runway.*

FREEZE SIMULATOR WHEN A/C COMES TO A FULL STOP

TRAINING PHASE: MANEUVER 3

-

<u>m3(scen_2) FAA Motion V1 Cut #1 T/O</u> Scenario 221 Button 6

Aircraft positioned on DFW Runway 36R and configured for takeoff with 10° Flaps. No Autothrottles.

DFW Twr	124.15
REGIONAL DEP	118.55
REGIONAL APP	118.42

Dept ATIS **"Tango"**

TANGO (T.O. R36R V1 and VR cuts)

> Dallas Ft. Worth International departure information TANGO, 1750 Zulu weather, Wind 170 at 10, visibility one quarter mile fog, ceiling 500 overcast, temperature 15, dewpoint 13, altimeter 29.92. Runway 36 Right in use. Advise you have information TANGO.

<u>Twr Freq:</u> **124.15**

<u>DFW Tower:</u> *Nasa 123, after departure, maintain runway heading, climb and maintain 3,500 hundred, wind 170 degrees at 10, Runway 36R, cleared for takeoff.*

After V1 # 1 engine failure (flameout)

Runway heading, during engine shutdown and aircraft cleanup commencing at 800¹ AGL.

<u>SIMULATOR WILL FREEZE AT 2000 FEET MSL</u>.

TRAINING PHASE: MANEUVER 4

<u>m4(scen_2) FAA E1 36R (Land Only S/S)</u> Scenario 222 Button 8

Aircraft positioned outside of CHARR heading 020° to intercept the ILS 36L Localizer, with #1 Engine shutdown, no Autothrottles, Autopilots on for approximately 15 seconds until aircraft stabilizes then OFF and Flight Directors off at OM. Microburst on approximately a 2 mile final.

DFW Twr	124.15
REGIONAL DEP	118.55
REGIONAL APP	118.42

Arr ATIS **"Mike"**

MIKE (Land R36 L or R36R)

> Dallas Ft. Worth International arrival information MIKE, 1810 Zulu weather, Wind 310 at 10, visibility five mile, ceiling 1100 overcast, temperature 15, dewpoint 13, altimeter 29.92. Runway 36 Left and runway 36 Right in use. Advise you have information MIKE.

<u>APP Freq:</u> **118.42**

<u>Regional APP:</u> *Nasa 123, continue heading 020, maintain 2500 until established on the localizer, cleared for ILS Runway 36L Approach, sidestep Runway 36R.*

ILS/DME Rwy 36**L**	354°	111.9
IBXN		

Approaching Outer Marker:

Regional APP: *Nasa 123 contact DFW tower on 124.15.*

After Nasa 123 contacts DFW tower:

DFW Tower: *Nasa 123, report runway 36R in sight.*

When Runway 36R reported in sight:

DFW Tower: *Nasa 123, wind 310 degrees at 10, cleared to land Runway 36R.*

After landing:

DFW Tower: *Nasa 123, after landing roll, stop on the runway.*

FREEZE SIMULATOR WHEN A/C COMES TO A FULL STOP

APPENDIX 5. EXPERIMENT PROTOCOL

#34, P17FRN4213 Date: 8/19/02 Motion: off Seat: R Training Sequence: 4-2-1-3 PF: John Doe (17 ldgs) PNF: John Doe ATC: John Doe Handedness: L Airline: Anonymous

Abnormalities	**Action**		**Comments**
Eval, crash on t/o	Print and put in air for landing		Has happened
Eval go around	Print, go to next scenario		Has happened
Trg, crash on t/o	Print and beam up, go to next training		Has happened
Trg go around	Print and beam up, go to next training		Has happened
Test, crash on t/o	Print and restart scenario		Has happened
Test, go around	Print, go to next scenario		Has happened
PIA instead of SS set up during trg	Freeze as soon as possible, print, do correct scenario		Has happened
Motion off during evaluation scenario	Turn motion on ASAP. If full scenario is flown, administer extra PFQ3, then continue.		Has happened
Time/Phase/Place	**Action**	**Responsible**	**Check/Comments**
Day before			
	Check that enough disk space on system next to VCRs for daily checks. If not, type “mv *.0 /tmp/chung/”		
	Check that pilot lounge “clean”	BC/jbc/TG/GS	
	Make sure that there are 16 blank tapes (and ask Gary to reorder when stock gets low)	BC/jbc/TG/GS	
	Determine PNF and Seat, check which counterbalancing cells are open for high and low experience	BC/jbc/TG/GS/ Jerry	
	Check coffee and paper cup stocks (in pilot lounge)	BC/jbc/TG/GS	
	Unwrap 16 and label at least 8 audio/video tapes (4 for backups), remove cover, label top and back • Name • Condition • Seat • PNF • Training Sequence • Tape recorder (1 in rack, 2, 3, 4 stacked on table--3 for backup of 2, 4 for backup of 1) and number, e.g., for first tape, 1/1; 2/1; BU 1/1;	BC/jbc/TG/GS	

#34, P17FRN4213 Date: 8/19/02 Motion: off Seat: R Training Sequence: 4-2-1-3 PF: John Doe (17 ldgs) PNF: John Doe ATC: John Doe Handedness: L Airline: Anonymous

Abnormalities	**Action**		**Comments**
Eval, crash on t/o	Print and put in air for landing		Has happened
Eval go around	Print, go to next scenario		Has happened
Trg, crash on t/o	Print and beam up, go to next training		Has happened
Trg go around	Print and beam up, go to next training		Has happened
	BU2/1). Note: 'BU' means 'BackUp' • Date Insert first tapes, have second tape ready on rack/recorder (hide label)		
	Paperwork in brown binder and folders • Protocols • Consent form: fill in PI fields and study • PFBriefing • Display examples • 3 PFQuestionnaires • PFFinal Comments • 4 PNFQuestionnaires • Flyers for pilot to recruit	BC/jbc/TG/GS	
Throughout	Keep track of protocol and mark GTM time in left hand column	BC/jbc/TG/GS	
	NASA experiment log	Jim/Charley	
	Check that correct maneuver set up (especially for ldg, where it can be seen on plot)	BC/jbc/TG/GS	
	Do tell them that training phase will be longest, and that they will be told what's coming. Do not tell them about any others, just that they'll do "some more flying."	BC/jbc/TG/GS	
	Hide anything that could give away purpose of study, pilots wander into control room.	All	
Before PF arrives			
	Buy refreshments (water and doughnuts, napkins) for morning and afternoon breaks	BC/jbc/TG/GS	
	Simulator set up for correct airline, see **Comments on Airline**	Jerry	

#34, P17FRN4213 Date: 8/19/02 Motion: off Seat: R Training Sequence: 4-2-1-3 PF: John Doe (17 ldgs) PNF: John Doe ATC: John Doe Handedness: L Airline: Anonymous

Abnormalities	**Action**		**Comments**
Eval, crash on t/o	Print and put in air for landing		Has happened
Eval go around	Print, go to next scenario		Has happened
Trg, crash on t/o	Print and beam up, go to next training		Has happened
Trg go around	Print and beam up, go to next training		Has happened
	configuration at the end of this document.		
	Simulator check ride	Jerry	
	Data recording set up	Charley	
	Color printer on, paper tray full, no color low indicator (call Gary)	BC/jbc/TG/GS	
	Feedback displays	Dave	
	Make sure coffee is ready all day	BC/jbc/TG/GS	
	Daily Check: motion, sound, visual, force feedback, graphs from sim and displays. Procedure in Phase 1 folder, password on back.	Jerry	
	Collect daily check paper work and label (1 p. color, 7 pp b/w)	BC/jbc/TG/GS	
	Set up sim for exp (FMC, etc)	Jerry	
	Communication check	Jerry	
	Engine sound full power	Jerry	
	"Motion on" and initialization	Jerry	
	Check cameras (must be on correct seat)	BC/jbc/TG/GS	
	Check video/audiotape sound w/ headphones on both recorders	BC/jbc/TG/GS	
After PF arrives			
In briefing room	Below 1000 total hrs/Above 1000 hrs in 747 and number of landings in the past 12 months.	BC/jbc/TG/GS	
	Sign consent form **three times, including authorization to videotape and release of data!** Also, address and phone number	BC/jbc/TG/GS	
	Briefing by experimenter. Show displays(mention to fly flight director as precisely as possible). "NASA test pilot."	BC/jbc/TG/GS	
	Briefing by Jerry, but no info on maneuvers. Fuel constant.	Jerry	

#34, P17FRN4213 Date: 8/19/02 Motion: off Seat: R Training Sequence: 4-2-1-3 PF: John Doe (17 ldgs) PNF: John Doe ATC: John Doe Handedness: L Airline: Anonymous

Abnormalities	**Action**		**Comments**
Eval, crash on t/o	Print and put in air for landing		Has happened
Eval go around	Print, go to next scenario		Has happened
Trg, crash on t/o	Print and beam up, go to next training		Has happened
Trg go around	Print and beam up, go to next training		Has happened
In control room	Determine motion group and maneuver training sequence based on PFQ1, 1st page (# of landings in the past 12 months, also 747-400 hours).	BC/jbc/TG/GS	
	Print out protocol w/ all available info filled in, ONE-SIDED for copying	BC/jbc/TG/GS	
	Configure simulator motion	Charley	
	Configure training sequence	Charley	
	Data collection standby	Charley	
	Audio/video standby On VCR 3, make sure that set for S-VHS	BC/jbc/TG/GS	
	Script standby	Charley	
	Communications standby	Charley	
PHASE I	**EVALUATION**		
PF and PNF enter cab	Safety briefing	Jerry	
	Establish communications	Charley	
	Initialize motion regardless of config	Charley	
	Washout motion if no-motion	Charley	
	Set-up	Charley/ PNF	
GTM:	**Play/Record on** (ALWAYS) Do VCR 3 first because of delays: 1) Wait for “00:00” display 2) Press “Rec” and wait for calibration to finish For VCR4: press “Rec” and “Pause” buttons at the same time to bring the VCR to the ready-to-record state. Wait for red circle. Press “Play” button *hard* to start the recording. Make sure that #s scroll.	BC/jbc/TG/GS	

#34, P17FRN4213 Date: 8/19/02 Motion: off Seat: R Training Sequence: 4-2-1-3 PF: John Doe (17 ldgs) PNF: John Doe ATC: John Doe Handedness: L Airline: Anonymous

Abnormalities	**Action**		**Comments**
Eval, crash on t/o	Print and put in air for landing		Has happened
Eval go around	Print, go to next scenario		Has happened
Trg, crash on t/o	Print and beam up, go to next training		Has happened
Trg go around	Print and beam up, go to next training		Has happened
	Briefing, no info on maneuvers & failures	PNF	
	Feedback displays on, collect data	Charley	
	Check: Motion status, Record (all scrolling?), HDG SEL		
GTM:	Fly Scenario 1 (V_R w/ PIA on 36L) # 1 failure. FD off at outer marker (Bobin). Turn autopilot off before diamond on FD is w/in ½ dot of centerline.	Charley/ PNF	
	Print displays (t/o 2 p., app. 1 p.) But don't beam up	Charley	
	Check hardcopies and printer messages and **erase** (for app., check that erased after turn)	Charley	
GTM:	Label hardcopies close to frame: Phase, Scenario/ Maneuver, Date	BC/jbc/TG/GS	
	Set-up	Charley/ PNF	
	Briefing, no info on maneuvers & failures	PNF	
	Feedback displays on, collect data	Charley	
	Check: Motion status, Record (all scrolling?), HDG SEL	BC/jbc/TG/GS	
GTM:	Fly Scenario 2 (V_1 cut w/SS to 36R) # 4 failure. **After** microburst, PNF mentions microburst so that pilot knows that it is not something wrong with sim. FD off at outer marker (Bobin). Turn autopilot off before diamond on	Charley/ PNF	

#34, P17FRN4213 Date: 8/19/02 Motion: off Seat: R Training Sequence: 4-2-1-3 PF: John Doe (17 ldgs) PNF: John Doe ATC: John Doe Handedness: L Airline: Anonymous

Abnormalities	**Action**		**Comments**
Eval, crash on t/o	Print and put in air for landing		Has happened
Eval go around	Print, go to next scenario		Has happened
Trg, crash on t/o	Print and beam up, go to next training		Has happened
Trg go around	Print and beam up, go to next training		Has happened
	FD is w/in ½ dot of centerline.		
	Print displays (t/o 2 p., app. 1 p.) But don't beam up	Charley	
	Check hardcopies and printer messages and **erase** (for app., check that erased after turn)	Charley	
	Label hardcopies close to frame: Phase, Scenario/ Maneuver, Date	BC/jbc/TG/GS	
	Turn off motion regardless of config, tell pilots	Charley	
	Data collection off	Charley	
PF and PNF exit cab to briefing room			
GTM:	Stop Audio/video taping, new tape?	BC/jbc/TG/GS	
	PF fills out PF Questionnaire 1 ("NASA test pilot," difference between Control Feel and Control Sensitivity, browse headings to see where to put comments, ensure correct comparison, "we want to know how well the sim represents the airplane," point out comparison (sim - a/c or sim-sim), make sure that they compare their performance in the sim with their presumed performance in the a/p under *exactly the same condition*)	BC/jbc/TG/GS	
	PNF fills out PNF Questionnaire 1	PNF	
	Food & Drink	BC/jbc/TG/GS	
	Detail brief pilot on displays collected during scenario 2. "Shows whether you are w/in Practical Test Standard tolerances." Point out if they violate something grossly (new	BC/jbc/TG/GS	

#34, P17FRN4213 Date: 8/19/02 Motion: off Seat: R Training Sequence: 4-2-1-3 PF: John Doe (17 ldgs) PNF: John Doe ATC: John Doe Handedness: L Airline: Anonymous

Abnormalities	**Action**		**Comments**
Eval, crash on t/o	Print and put in air for landing		Has happened
Eval go around	Print, go to next scenario		Has happened
Trg, crash on t/o	Print and beam up, go to next training		Has happened
Trg go around	Print and beam up, go to next training		Has happened
	after P01MRT ignored speed—mention to follow flight director.		
	Bathroom		
PHASE II	**TRAINING:** fail opposite engine. FD always off at outer marker (Bobin). Turn autopilot off before diamond on FD is w/in ½ dot of centerline.		
In control room	Training sequence standby	Charley	
	Data collection standby	Charley	
	Audio/video standby	BC/jbc/TG/GS	
	Feedback displays standby	Charley	
PF and PNF enter cab			
	Establish communications	Charley	
	Initialize motion regardless of config	Charley	
	Washout motion if no-motion run	Charley	
Training 1	Set-up	Charley/ PNF	
GTM:	**Play/Record on: All scrolling?**	BC/jbc/TG/GS	
	Briefing, **announce failure/weather. First of three.**	PNF	
	Feedback displays on, collect data	Charley	
	Check: Motion status, Record (all scrolling?), HDG SEL	BC/jbc/TG/GS	
GTM:	Fly first training maneuver	Charley/ PNF	
	Print and beam up display(s)	Charley	
	Check hardcopies and printer messages. **Erase displays when pilots ready**	Charley	
	Label hardcopies close to frame:	BC/jbc/TG/GS	

#34, P17FRN4213 Date: 8/19/02 Motion: off Seat: R Training Sequence: 4-2-1-3 PF: John Doe (17 ldgs) PNF: John Doe ATC: John Doe Handedness: L Airline: Anonymous

Abnormalities	**Action**		**Comments**
Eval, crash on t/o	Print and put in air for landing		Has happened
Eval go around	Print, go to next scenario		Has happened
Trg, crash on t/o	Print and beam up, go to next training		Has happened
Trg go around	Print and beam up, go to next training		Has happened
	Phase, Scenario/ Maneuver, Date		
	Set-up	Charley/ PNF	
	Briefing, **announce failure/weather. 2nd of 3.**	Charley/ PNF	
	Feedback displays on, collect data	Charley	
	Check: Motion status, Record (all scrolling?), HDG SEL		
GTM:	Fly first training maneuver 2nd time	Charley/ PNF	
	Print and beam up display(s)	Charley	
	Check hardcopies and printer messages. **Erase displays when pilot ready**	Charley	
	Label hardcopies close to frame: Phase, Scenario/ Maneuver, Date	BC/jbc/TG/GS	
	Set-up	Charley/ PNF	
	Briefing, announce failure/weather. Last of 3.	Charley/ PNF	
	Feedback displays on, collect data	Charley	
	Check: Motion status, Record (all scrolling?), HDG SEL	BC/jbc/TG/GS	
GTM:	Fly first training maneuver 3rd time	Charley/ PNF	
	Print and beam up display(s)	Charley	
	Check hardcopies and printer messages. **Erase displays when pilot ready**	Charley	
	Label hardcopies close to frame: Phase, Scenario/ Maneuver, Date	BC/jbc/TG/GS	

#34, P17FRN4213 Date: 8/19/02 Motion: off Seat: R Training Sequence: 4-2-1-3 PF: John Doe (17 ldgs) PNF: John Doe ATC: John Doe Handedness: L Airline: Anonymous

Abnormalities	**Action**		**Comments**
Eval, crash on t/o	Print and put in air for landing		Has happened
Eval go around	Print, go to next scenario		Has happened
Trg, crash on t/o	Print and beam up, go to next training		Has happened
Trg go around	Print and beam up, go to next training		Has happened
Training 2	Set-up	Charley/ PNF	
	Briefing, **announce failure/weather. First of 3.**	Charley/ PNF	
	Feedback displays on, collect data	Charley	
	Check: Motion status, Record (all scrolling?), HDG SEL	BC/jbc/TG/GS	
GTM:	Fly 2nd training maneuver	Charley/ PNF	
	Print and beam up display(s)	Charley	
	Check hardcopies and printer messages. **Erase displays when pilots ready**	Charley	
	Label hardcopies close to frame: Phase, Scenario/ Maneuver, Date	BC/jbc/TG/GS	
	Set-up	Charley/ PNF	
	Briefing, **announce failure/weather. 2nd of 3.**	Charley/ PNF	
	Feedback displays on, collect data	Charley	
	Check: Motion status, Record (all scrolling?), HDG SEL	BC/jbc/TG/GS	
GTM:	Fly 2nd training maneuver 2nd time	Charley/ PNF	
	Print and beam up display(s)	Charley	
	Check hardcopies and printer messages. **Erase displays when pilot ready**	Charley	
	Label hardcopies close to frame: Phase, Scenario/ Maneuver, Date	BC/jbc/TG/GS	
	Set-up	Charley/	

#34, P17FRN4213 Date: 8/19/02 Motion: off Seat: R Training Sequence: 4-2-1-3 PF: John Doe (17 ldgs) PNF: John Doe ATC: John Doe Handedness: L Airline: Anonymous

Abnormalities	**Action**		**Comments**
Eval, crash on t/o	Print and put in air for landing		Has happened
Eval go around	Print, go to next scenario		Has happened
Trg, crash on t/o	Print and beam up, go to next training		Has happened
Trg go around	Print and beam up, go to next training		Has happened
		PNF	
	Briefing, **announce failure/weather.** Last of 3.	Charley/ PNF	
	Feedback displays on, collect data	Charley	
	Check: Motion status, Record (all scrolling?), HDG SEL	BC/jbc/TG/GS	
GTM:	Fly 2nd training maneuver 3rd time	Charley/ PNF	
	Print and beam up display(s)	Charley	
	Check hardcopies and printer messages. **Erase displays when pilot ready**	Charley	
	Label hardcopies close to frame: Phase, Scenario/ Maneuver, Date	BC/jbc/TG/GS	
	Check audio/videotape. NEW TAPE? (make sure that done with discussion before changing!)	BC/jbc/TG/GS	
	Verify that new tape is correctly labeled, stow used tape, put third tape ready on recorder or rack, respectively	BC/jbc/TG/GS	
Training 3	Set-up	Charley/ PNF	
	Briefing, **announce failure/weather. First of 3.**	Charley/ PNF	
	Feedback displays on, collect data	Charley	
	Check: Motion status, Record (all scrolling?), HDG SEL	BC/jbc/TG/GS	
GTM:	Fly 3rd training maneuver	Charley/ PNF	
	Print and beam up display(s)	Charley	

#34, P17FRN4213 Date: 8/19/02 Motion: off Seat: R Training Sequence: 4-2-1-3 PF: John Doe (17 ldgs) PNF: John Doe ATC: John Doe Handedness: L Airline: Anonymous

Abnormalities	**Action**		**Comments**
Eval, crash on t/o	Print and put in air for landing		Has happened
Eval go around	Print, go to next scenario		Has happened
Trg, crash on t/o	Print and beam up, go to next training		Has happened
Trg go around	Print and beam up, go to next training		Has happened
	Check hardcopies and printer messages. **Erase displays when pilots ready**	Charley	
	Label hardcopies close to frame: Phase, Scenario/ Maneuver, Date	BC/jbc/TG/GS	
	Set-up	Charley/ PNF	
	Briefing, **announce failure/weather. 2nd of 3.**	Charley/ PNF	
	Feedback displays on, collect data	Charley	
	Check: Motion status, Record (all scrolling?), HDG SEL	BC/jbc/TG/GS	
GTM:	Fly 3rd training maneuver 2nd time	Charley/ PNF	
	Print and beam up display(s)	Charley	
	Check hardcopies and printer messages. **Erase displays when pilot ready**	Charley	
	Label hardcopies close to frame: Phase, Scenario/ Maneuver, Date	BC/jbc/TG/GS	
	Set-up	Charley/ PNF	
	Briefing, announce failure/weather. Last of 3.	Charley/ PNF	
	Feedback displays on, collect data	Charley	
	Check: Motion status, Record (all scrolling?), HDG SEL	BC/jbc/TG/GS	
GTM:	Fly 3rd training maneuver 3rd time	Charley/ PNF	
	Print and beam up display(s)	Charley	
	Label hardcopies close to frame:	BC/jbc/TG/GS	

#34, P17FRN4213 Date: 8/19/02 Motion: off Seat: R Training Sequence: 4-2-1-3 PF: John Doe (17 ldgs) PNF: John Doe ATC: John Doe Handedness: L Airline: Anonymous

Abnormalities	**Action**		**Comments**
Eval, crash on t/o	Print and put in air for landing		Has happened
Eval go around	Print, go to next scenario		Has happened
Trg, crash on t/o	Print and beam up, go to next training		Has happened
Trg go around	Print and beam up, go to next training		Has happened
	Phase, Scenario/ Maneuver, Date		
	Check hardcopies and printer messages. **Erase when pilot ready**	Charley	
Training 4	Set-up	Charley/ PNF	
	Briefing, **announce failure/weather. First of 3.**	Charley/ PNF	
	Feedback displays on, collect data	Charley	
	Check: Motion status, Record (all scrolling?), HDG SEL	BC/jbc/TG/GS	
GTM:	Fly 4th training maneuver	Charley/ PNF	
	Print and beam up display(s)	Charley	
	Check hardcopies and printer messages. **Erase displays when pilots ready**	Charley	
	Label hardcopies close to frame: Phase, Scenario/ Maneuver, Date	BC/jbc/TG/GS	
	Set-up	Charley/ PNF	
	Briefing, **announce failure/weather. 2nd of 3.**	Charley/ PNF	
	Feedback displays on, collect data	Charley	
	Check: Motion status, Record (all scrolling?), HDG SEL	BC/jbc/TG/GS	
GTM	Fly 4th training maneuver 2nd time	Charley/ PNF	
	Print and beam up display(s)	Charley	
	Check hardcopies and printer messages. **Erase displays when**	Charley	

#34, P17FRN4213 Date: 8/19/02 Motion: off Seat: R Training Sequence: 4-2-1-3 PF: John Doe (17 ldgs) PNF: John Doe ATC: John Doe Handedness: L Airline: Anonymous

Abnormalities	Action		Comments
Eval, crash on t/o	Print and put in air for landing		Has happened
Eval go around	Print, go to next scenario		Has happened
Trg, crash on t/o	Print and beam up, go to next training		Has happened
Trg go around	Print and beam up, go to next training		Has happened
	pilot ready		
	Label hardcopies close to frame: Phase, Scenario/ Maneuver, Date	BC/jbc/TG/GS	
	Set-up	Charley/ PNF	
	Briefing, announce failure/weather. Last of 3.	Charley/ PNF	
	Feedback displays on, collect data	Charley	
	Check: Motion status, Record (all scrolling?), HDG SEL	BC/jbc/TG/GS	
GTM:	Fly 4th training maneuver 3rd time	Charley/ PNF	
	Print and beam up display(s)	Charley	
	Check hardcopies and printer messages. **Erase when pilot ready**	Charley	
	Label hardcopies close to frame: Phase, Scenario/ Maneuver, Date	BC/jbc/TG/GS	
	Ensure understandability of PFQ1	BC/jbc/TG/GS	
	Turn off motion regardless of config, tell pilots	Charley	
	Data collection off	Charley	
PF and PNF exit cab to briefing room			
	Stop Audio/video taping, new tape?	BC/jbc/TG/GS	
	PF fills out PF Questionnaire 2	BC/jbc/TG/GS	
	PNF fills out PNF Questionnaire 2	PNF	
	Lunch	Jerry	
	Bathroom		
PHASE III	**TESTING ALL WITH MOTION**		
PF and PNF enter			

#34, P17FRN4213 Date: 8/19/02 Motion: off Seat: R Training Sequence: 4-2-1-3 PF: John Doe (17 ldgs) PNF: John Doe ATC: John Doe Handedness: L Airline: Anonymous

Abnormalities	**Action**		**Comments**
Eval, crash on t/o	Print and put in air for landing		Has happened
Eval go around	Print, go to next scenario		Has happened
Trg, crash on t/o	Print and beam up, go to next training		Has happened
Trg go around	Print and beam up, go to next training		Has happened
cab			
	Establish communications	Charley	
	Initialize motion	Charley	
	Do Not Wash it Out	Charley	
	Set-up	Charley/ PNF	
GTM:	Play/Record on: All scrolling?	BC/jbc/TG/GS	
Testing 1	Briefing, no info on maneuvers & failures	Charley/ PNF	
	Feedback displays on, collect data	Charley	
	Check: **Motion status,** **Record (all scrolling?),** **HDG SEL**	BC/jbc/TG/GS	
GTM:	Fly Scenario 1 (V_R w/ PIA on 36L) # 1 failure. FD off at outer marker (Bobin). Turn autopilot off before diamond on FD is w/in ½ dot of centerline.	Charley/ PNF	
	Print displays (t/o 2 p., app. 1 p.) But don't beam up	Charley	
	Check hardcopies and printer messages and **erase** (for app., check that erased after turn)	Charley	
	Label hardcopies close to frame: Phase, Scenario/ Maneuver, Date	BC/jbc/TG/GS	
	Set-up	Charley/ PNF	
	Briefing, no info on maneuvers & failures	Charley/ PNF	
	Feedback displays on, collect data	Charley	
	Check: **Motion status,** **Record (all scrolling?),** **HDG SEL**	BC/jbc/TG/GS	

#34, P17FRN4213 Date: 8/19/02 Motion: off Seat: R Training Sequence: 4-2-1-3 PF: John Doe (17 ldgs) PNF: John Doe ATC: John Doe Handedness: L Airline: Anonymous

Abnormalities	**Action**		**Comments**
Eval, crash on t/o	Print and put in air for landing		Has happened
Eval go around	Print, go to next scenario		Has happened
Trg, crash on t/o	Print and beam up, go to next training		Has happened
Trg go around	Print and beam up, go to next training		Has happened
GTM:	Fly Scenario 2 (V_1 cut w/SS to 36R) # 4 failure. FD off at outer marker (Bobin). Turn autopilot off before diamond on FD is w/in ½ dot of centerline.	Charley/ PNF	
	Print displays (t/o 2 p., app. 1 p.) But don't beam up	Charley	
	Check hardcopies and printer messages and **erase** (for app., check that erased after turn)	Charley	
	Label hardcopies close to frame: Phase, Scenario/ Maneuver, Date	BC/jbc/TG/GS	
	Ensure understandability of PFQ2	BC/jbc/TG/GS	
	Turn off motion regardless of config, tell pilots	Charley	
	Data collection off	Charley	
PF and PNF exit cab to briefing room			
GTM:	Stop Audio/video taping, **NEW TAPE?**	BC/jbc/TG/GS	
	Verify that new tape is correctly labeled, stow used tape	BC/jbc/TG/GS	
	PF fills out PF Questionnaire 3	BC/jbc/TG/GS	
	PNF fills out PNF Questionnaire 3	PNF	
	Coffee	BC/jbc/TG/GS	
	Bathroom		
PF and PNF enter cab			
	Establish communications	Charley	
	Initialize motion	Charley	
	Do Not Wash it Out	Charley	
	Set-up	Charley/ PNF	
GTM:	**Play/Record on: All scrolling?**	BC/jbc/TG/GS	
Testing 2	Briefing, no info on maneuvers & failures	Charley/ PNF	

#34, P17FRN4213 Date: 8/19/02 Motion: off Seat: R Training Sequence: 4-2-1-3 PF: John Doe (17 ldgs) PNF: John Doe ATC: John Doe Handedness: L Airline: Anonymous

Abnormalities	Action		Comments
Eval, crash on t/o	Print and put in air for landing		Has happened
Eval go around	Print, go to next scenario		Has happened
Trg, crash on t/o	Print and beam up, go to next training		Has happened
Trg go around	Print and beam up, go to next training		Has happened
	Feedback displays on, collect data	Charley	
	Check: **Motion status,** **Record (all scrolling?),** **HDG SEL**	BC/jbc/TG/GS	
GTM:	Fly Scenario 1 (V_R w/ PIA on 36L) # 1 failure. FD off at outer marker (Bobin). Turn autopilot off before diamond on FD is w/in ½ dot of centerline.	Charley/ PNF	
	Print displays (t/o 2 p., app. 1 p.) But don't beam up	Charley	
	Check hardcopies and printer messages and **erase** (for app., check that erased after turn)	Charley	
	Label hardcopies close to frame: Phase, Scenario/ Maneuver, Date	BC/jbc/TG/GS	
	Set-up	Charley/ PNF	
	Briefing, no info on maneuvers & failures	Charley/ PNF	
	Feedback displays on, collect data	Charley	
	Check: **Motion status,** **Record (all scrolling?),** **HDG SEL**	BC/jbc/TG/GS	
GTM:	Fly Scenario 2 (V_1 cut w/SS to 36R) # 4 failure. FD off at outer marker (Bobin). Turn autopilot off before diamond on FD is w/in ½ dot of centerline.	Charley/ PNF	
	Print displays (t/o 2 p., app. 1 p.) But don't beam up	Charley	
	Check hardcopies and printer messages and **erase** (for app.,	Charley	

#34, P17FRN4213 Date: 8/19/02 Motion: off Seat: R Training Sequence: 4-2-1-3 PF: John Doe (17 ldgs) PNF: John Doe ATC: John Doe Handedness: L Airline: Anonymous

Abnormalities	**Action**		**Comments**
Eval, crash on t/o	Print and put in air for landing		Has happened
Eval go around	Print, go to next scenario		Has happened
Trg, crash on t/o	Print and beam up, go to next training		Has happened
Trg go around	Print and beam up, go to next training		Has happened
	check that erased after turn)		
	Label hardcopies close to frame: Phase, Scenario/ Maneuver, Date	BC/jbc/TG/GS	
	Ensure understandability of PFQ3	BC/jbc/TG/GS	
	Turn off motion regardless of config, tell pilots	Charley	
	Data collection off	Charley	
PF and PNF exit cab to debriefing room			
GTM:	Stop Audio/video taping	BC/jbc/TG/GS	
	PF fills out Final Comments	BC/jbc/TG/GS	
	PNF fills out PFQ4	BC/jbc/TG/GS	
	Ensure understandability of PFFC	BC/jbc/TG/GS	
Pilot leaves	THANK YOU & send friends!	All	
	Experimenter talks to PNF	BC/jbc/TG/GS	
POST EXPERIMENT CHORES (Please fill out and give dates)			
	Secure data and label	Dave	
	Back-up data	Dave	
	FTP data to Volpe	Dave	
	Secure videotapes and verify label	BC/jbc/TG/GS	
	Secure paperwork, incl. NASA log & protocol	BC/jbc/TG/GS	
	Copy paperwork	BC/jbc/TG/GS	
	Double check paperwork copies	BC/jbc/TG/GS	
	File paperwork and videotapes	BC/jbc/TG/GS	
	Send data on CD to Volpe	Dave	
	Send paperwork to Volpe (bring to Sally in shipping in Bill's building)	BC/jbc/TG/GS	
	Send videotapes to Volpe (ditto)	BC/jbc/TG/GS	

Comments on Airline configuration:

If the pilot is from Northwest airline then the Northwest configuration is selected. For UAL pilots, the UAL configuration is used.

For other airline's pilots, ask whether they use the dual or single cue flight director and then select the UAL or NWA configuration respectively.

UAL configuration (default), as described by Jerry**:**
- The UAL PFD is a dual cue flight director.
- The radio altimeter is at the bottom of the attitude indicator just above the localizer scale.
- The DH is displayed beneath the bottom right corner of the attitude indicator, and the MDA is displayed above the top right corner of the attitude indicator.
- On landing there are aural callouts for 50 ft, 30 ft and 10 ft.

Northwest configuration, as described by Jerry:
- The Northwest PFD is a single cue flight director.
- The radio altimeter is displayed above the top right corner of the attitude indicator and so is the DH.
- The MDA is displayed below the bottom right corner of the attitude indicator.
- On landing the radio altimeter emits aural tones at 100 ft, 35 ft and 20 ft.

PILOT FLYING – QUESTIONNAIRE 1

General Information
Today's Date: _____________
Time: _____________
First Name: ________________Last Name:_________________
Currently flying as a B-747-400 Captain ____First Officer____
Name of PNF during experiment: _______________________

Experience in airplanes
Last time you have flown the B747-400 airplane: ___________

Number of landings in B747-400 airplane in past 12 months: _______

Pilot time in B747 airplanes: ___________ hours

Pilot time in glass cockpit airplanes (incl. B747): ___________ hours

Total flight time: ___________ hours

Experience in 747-400 full flight simulator (Level C/D) before today:

Number of simulator landings in past 12 months: ________

Pilot time in 747-400 simulator: ___________ hours

Last 747-400 full flight simulator flown (Level C or D):

When: _____________Where: _____________________

Instructions for Questionnaires:

1) In these questionnaires you are asked to evaluate the NASA 747-400 simulator. You are asked to make one of two comparisons, as indicated on each page:
   a) the NASA 747-400 simulator (as flown today) to the B747-400 airplane
   b) the NASA 747-400 simulator today to the last 747-400 simulator you have flown.

2) Please base all of your judgments on the **maneuvers that you have flown so far today or, if applicable, since you have filled out the last questionnaire**.

3) For comparisons with the airplane, you may have to base your judgments on how you would **expect** the airplane to behave during these maneuvers.

4) Please indicate each judgment by placing an **X** in the appropriate box. You may be asked to elaborate on your judgment in the space provided. Feel free to elaborate even if you are not specifically asked to do so.

Control Feel

Compare the NASA 747-400 **simulato**r to the B747-400 **airplane** in terms of **control loading,** i.e., **the amount of effort you need to operate the controls.**

Note: Control sensitivity (amount of response generated by the control inputs) will be treated on the next page.

The **control feel** in the NASA 747-400 simulator was...

Controls	1	2	3	4	5	6	7
	much lighter than airplane	moderately lighter	slightly lighter	just like the airplane	slightly heavier	moderately heavier	much heavier than airplane
Rudder input							
Aileron input							
Elevator input							
Throttles							
Yaw trim input							
Roll trim input							
Pitch trim input							
Overall control feel							
Please elaborate if control feel is different from airplane							

Control Sensitivity

Compare the NASA 747-400 **simulato**r to the B747-400 **airplane** in terms of the **amount of response generated by the control actions (control sensitivity).**

The control **sensitivity** of the NASA 747-400 simulator was...

Controls	1	2	3	4	5	6	7
	much less sensitive than airplane	moderately less sensitive	slightly less sensitive	just like the airplane	slightly more sensitive	moderately more sensitive	much more sensitive than airplane
Yaw control							
Roll control							
Pitch control							
Throttle control							
Overall control sensitivity							
Please elaborate if control sensitivity is different from airplane							

Handling Qualities

Compare the NASA 747-400 **simulator** to the B747-400 **airplane** in terms of **ease and precision in performing the tasks.**

Remember: You have already evaluated control feel and sensitivity.

The **handling qualities** of the NASA747-400 simulator were...

Task	1	2	3	4	5	6	7
	much worse than airplane	moderately worse	slightly worse	just like the airplane	slightly better	moderately better	much better than airplane
Pitch control							
Bank angle control							
Yaw control							
Altitude control							
Heading control							
Airspeed control							
Overall handling qualities							
Please elaborate if handling qualities are different from airplane							

Control Strategy and Technique

Compare the NASA 747-400 **simulator** to the B747-400 **airplane** in terms of **how you flew the maneuvers and compensated for mechanical and weather disturbances,** i.e., **whether you had to adapt the sequence, amount,** and **type of controls you used.**

My **strategy and technique** to fly the maneuvers in the NASA 747-400 simulator was...

Maneuver	1	2	3	4	Please elaborate if different
	very different than in airplane	moderately different	slightly different	the same as in airplane	
Engine cut at V_1					
Engine cut at V_R					
Engine-out straight-in approach/ldg					
Engine-out sidestep landing					

Other Cues

Compare the NASA 747-400 **simulato**r to the B747-400 **airplane** in terms of **any other cues** perceived during the maneuvers.

Remember: You have already evaluated control feel, sensitivity, and handling qualities.

I perceived **other cues** in the NASA 747-400 simulator during each maneuver as…

Maneuver	1	2	3	4	Please elaborate if different than airplane
	very different than in airplane	moderately different	slightly different	the same as in airplane	
Engine cut at V_1					
Engine cut at V_R					
Engine-out straight-in approach/ldg					
Engine-out sidestep landing					

Pilot Performance

Compare your performance in the NASA 747-400 **simulator** to your performance in the B747-400 **airplane.**

My performance in the NASA747-400 simulator was...

Task	1	2	3	4	5	6	7
	much worse than in airplane	moderately worse	slightly worse	just like in the airplane	slightly better	moderately better	much better than in airplane
Engine cut at V_1							
Engine cut at V_R							
Engine-out straight-in approach/ldg							
Engine-out sidestep landing							
Please elaborate if different from performance in airplane							

Physical and Mental Workload

Compare the NASA 747-400 **simulator** to the B747-400 **airplane** in terms of the **physical and mental workload** associated with flying the maneuvers.

Workload in the NASA 747-400 simulator was…

	1	2	3	4	5	6	7
Type of Workload	much higher than airplane	moderately higher	slightly higher	the same as airplane	slightly lower	moderately lower	much lower than airplane
Physical							
Please elaborate if physical workload is different from airplane							
Mental							
Please elaborate if mental workload is different from airplane							

Physical Comfort

Compare the NASA 747-400 **simulator** to the **last 747-400 SIMULATOR** you have flown in terms of the **absence of nausea or simulator-induced disorientation.**

My physical comfort in the NASA 747-400 simulator was...

	1	2	3	4	5	6	7
	much worse than in the last simulator	moderately worse	slightly worse	just like the last simulator	slightly better	moderately better	much better than in the last simulator
Overall comfort							
Please elaborate if comfort is different from last simulator							

Acceptability

Compare the NASA 747-400 simulator to
the **last 747-400 SIMULATOR you have flown**
in terms of your **acceptance** based on your perception of the
presence or absence of deficiencies that might affect your flying.

Acceptability of the NASA 747-400 simulator was...

	1	2	3	4	5	6	7
	much worse than last simulator flown	moderately worse	slightly worse	just like the last simulator flown	slightly better	moderately better	much better than last simulator flown
Overall acceptability							
Please elaborate if acceptability is different from last simulator							

PILOT FLYING – QUESTIONNAIRE 2

General Information
Today's Date: _____________

Time: _____________

First Name: _________________ Last Name: _________________

Currently flying as a B-747-400 Captain ____First Officer____

Name of PNF during experiment: _______________________

Instructions for Questionnaire 2

1) As in the previous questionnaire, you are asked to make one of two comparisons, as indicated on each page:
   a) the NASA 747-400 simulator (as flown today) to the B747-400 airplane
   b) the NASA 747-400 simulator today to the last 747-400 simulator you have flown.

2) Please answer all questions **based on the maneuvers that you have flown since Questionnaire 1**. Some questions are the same as in Questionnaire 1. This is to see whether your opinions have changed after spending more time in the simulator.

3) Again, for comparisons with the airplane, you may have to base your judgments on how you would expect the airplane to behave during these maneuvers.

4) Please indicate each judgment by placing an X in the appropriate box. You may be asked to elaborate on your judgment in the space provided. Feel free to elaborate even if you are not specifically asked to do so.

Gaining Proficiency

Compare the **NASA 747-400 simulator** to the **last 747-400 simulator** you have flown in terms of the ease of gaining the proficiency necessary to perform satisfactorily in controlling the airplane.

Gaining proficiency in the NASA simulator compared to the last simulator was…

	1	2	3	4	5	6	7
	much harder	moderately harder	slightly harder	just like in the last simulator	slightly easier	moderately easier	much easier
Engine cut at V_1							
Engine cut at V_R							
Engine-out straight-in approach/ldg							
Engine-out sidestep landing							
Overall gain of proficiency							
Please elaborate if gaining proficiency is different from the last simulator							

Control Feel

Compare the NASA 747-400 simulator to the B747-400 airplane in terms of **control loading**, i.e., the **amount of effort** you need to operate the controls.

Note: Control sensitivity (amount of response generated by the control inputs) will be treated on the next page).

During training, the **control feel** in the NASA 747-400 simulator was...

	1	2	3	4	5	6	7
	much lighter than airplane	moderately lighter	slightly lighter	just like the airplane	slightly heavier	moderately heavier	much heavier than airplane
Overall control feel							

If overall control feel is different from airplane, please indicate which of the controls mainly affect your opinion

- ❑ Rudder input
- ❑ Aileron input
- ❑ Elevator input
- ❑ Throttles
- ❑ Yaw trim input
- ❑ Roll trim input
- ❑ Pitch trim input
- ❑ All of the above

Control Sensitivity

Compare the **NASA 747-400** simulator to the **B747-400 airplane** in terms of the amount of response generated by the control actions (control sensitivity).

During training, the **control sensitivity** of the NASA 747-400 simulator was...

	1	2	3	4	5	6	7
	much less sensitive than airplane	moderately less sensitive	slightly less sensitive	just like the airplane	slightly more sensitive	moderately more sensitive	much more sensitive than airplane
Overall control sensitivity							

If overall control sensitivity is different from airplane, please indicate which of the controls mainly affect your overall opinion

- ❑ Yaw control
- ❑ Roll control
- ❑ Pitch control
- ❑ Throttle control
- ❑ All of the above

Handling Qualities

Compare the NASA 747-400 **simulator** to the B747-400 **airplane** in terms of **ease and precision** in performing the tasks.

Remember: You have already evaluated control feel and sensitivity.

During training, the **handling qualities** of the NASA747-400 simulator were...

	1	2	3	4	5	6	7
	much worse than airplane	moderately worse	slightly worse	just like the airplane	slightly better	moderately better	much better than airplane
Overall handling qualities							

If overall handling qualities are different from the airplane, please indicate which of the tasks mainly affect your opinion

- ❑ Pitch control
- ❑ Bank angle control
- ❑ Yaw control
- ❑ Altitude control
- ❑ Heading control
- ❑ Airspeed control
- ❑ All of the above

Control Strategy and Technique

Compare the NASA 747-400 **simulator** to the B747-400 **airplane**
in terms of how you flew the maneuvers and compensated for mechanical and weather disturbances, i.e., whether you had to adapt the sequence, amount, and type of controls you used.

During training, my **strategy & technique** to fly the maneuvers in the NASA 747-400 simulator was...

	1	2	3	4
	very different than in airplane	moderately different	slightly different	the same as in airplane
Overall control strategy and technique				

If overall control strategy and technique are different from the airplane, please indicate during which of the maneuvers and how

- ❑ Engine cut at V_1
- ❑ Engine cut at V_R
- ❑ Engine-out straight-in approach/ldg
- ❑ Engine-out side-step landing
- ❑ All of the above

Other Cues

Compare the NASA 747-400 **simulato**r to the B747-400 **airplane** in terms of **any other cues** perceived during the maneuvers.

Remember: You have already evaluated control feel, sensitivity, and handling qualities.

During training, I perceived **other cues** in the NASA 747-400 simulator during each maneuver as…

Maneuver	1	2	3	4	Please elaborate if different than airplane
	very different than in airplane	moderately different	slightly different	the same as in airplane	
Engine cut at V_1					
Engine cut at V_R					
Engine-out straight-in approach/ldg					
Engine-out sidestep landing					

Physical and Mental Workload

Compare the NASA 747-400 **simulator** to the B747-400 **airplane**
in terms of the physical and mental workload
associated with flying the maneuvers.

During training, **workload** in the NASA 747-400 simulator was …

	1	2	3	4	5	6	7
Type of Workload	much higher than airplane	moderately higher	slightly higher	the same as airplane	slightly lower	moderately lower	much lower than airplane
Physical							
Please elaborate if physical workload is different from airplane							
Mental							
Please elaborate if mental workload is different from airplane							

Physical Comfort

Compare the NASA 747-400 simulator to the last 747-400 SIMULATOR you have flown in terms of the absence of nausea or simulator-induced disorientation.

During training, my physical comfort in the NASA 747-400 simulator was...

	1	2	3	4	5	6	7
	much worse than in the last simulator	moderately worse	slightly worse	just like the last simulator	slightly better	moderately better	much better than in the last simulator
Overall comfort							
Please elaborate if comfort is different from last simulator							

Acceptability

Compare the NASA 747-400 to
the **last 747-400 SIMULATOR** you have flown
in terms of your acceptance based on your perception
of the presence or absence of **deficiencies that might affect your flying.**

Acceptability of the NASA 747-400 simulator was**...**

	1	2	3	4	5	6	7
	much worse than last simulator flown	moderately worse	slightly worse	just like the last simulator flown	slightly better	moderately better	much better than last simulator flown
Overall acceptability							
Please elaborate if acceptability is different from last simulator							

PILOT FLYING – QUESTIONNAIRE 3

General Information

Today's Date: _____________

Time: _____________

First Name: __________________Last Name: _________________

Currently flying as a B-747-400 Captain ____First Officer____

Name of PNF during experiment: _______________________

Instructions for Questionnaire 3:

1) As in the previous questionnaires, you are asked to make one of two comparisons, as indicated on each page:

   a) the NASA 747-400 simulator (as flown today) to the B747-400 airplane
   b) the NASA 747-400 simulator today to the last 747-400 simulator you have flown.

2) Please answer all questions based on the maneuvers that you have flown after the break. Some questions are the same as in the previous questionnaires. This is to see whether your opinions have changed after performing the last two scenarios in the simulator.

3) Again, for comparisons with the airplane, you may have to base your judgments on how you would expect the airplane to behave during these maneuvers.

4) Please indicate each judgment by placing an X in the appropriate box. You may be asked to elaborate on your judgment in the space provided. Feel free to elaborate even if you are not specifically asked to do so.

Control Feel

Compare the NASA 747-400 **simulato**r to the B747-400 **airplane** in terms of **control loading,** i.e., **the amount of effort you need to operate the controls.**

Note: The amount of response generated by the control inputs will be treated on the next page.

After the break, the **control feel** in the NASA 747-400 simulator was...

Controls	1	2	3	4	5	6	7
	much lighter than airplane	moderately lighter	slightly lighter	just like the airplane	slightly heavier	moderately heavier	much heavier than airplane
Rudder input							
Aileron input							
Elevator input							
Throttles							
Yaw trim input							
Roll trim input							
Pitch trim input							
Overall control feel							

Control Sensitivity

Compare the NASA 747-400 **simulato**r to the B747-400 **airplane** in terms of the **amount of response generated by the control actions (control sensitivity).**

After the break, the control **sensitivity** of the NASA 747-400 simulator was**...**

Controls	1	2	3	4	5	6	7
	much less sensitive than airplane	moderately less sensitive	slightly less sensitive	just like the airplane	slightly more sensitive	moderately more sensitive	much more sensitive than airplane
Yaw control							
Roll control							
Pitch control							
Throttle control							
Overall control sensitivity							
Please elaborate if control sensitivity is different from airplane							

Handling Qualities

Compare the NASA 747-400 **simulator** to the B747-400 **airplane** in terms of **ease and precision in performing the tasks.**

Remember: You have already evaluated control feel and sensitivity.

After the break, the **handling qualities** of the NASA747-400 simulator were...

Tasks	1	2	3	4	5	6	7
	much worse than airplane	moderately worse	slightly worse	just like the airplane	slightly better	moderately better	much better than airplane
Pitch control							
Bank angle control							
Yaw control							
Altitude control							
Heading control							
Airspeed control							
Overall handling qualities							
Please elaborate if handling qualities are different than airplane							

Control Strategy and Technique

Compare the NASA 747-400 **simulato**r to the B747-400 **airplane** in terms of **how you flew the maneuvers and compensated for mechanical and weather disturbances,** i.e., whether you had to **adapt the sequence, amount, and type of controls you used**.

After the break, my **control strategy and technique** to perform the maneuvers in the NASA 747-400 simulator was...

Tasks	1	2	3	4	Please elaborate if different
	very different than in airplane	moderately different	slightly different	the same as in airplane	
Engine cut at V_1					
Engine cut at V_R					
Engine-out straight-in approach/ldg					
Engine-out sidestep landing					

Other Cues

Compare the NASA 747-400 **simulato**r to the B747-400 **airplane** in terms of **any other cues** perceived during the maneuvers.

Remember: You have already evaluated control feel, sensitivity and handling qualities.

After the break, I perceived **other cues** in the NASA 747-400 simulator during each maneuver as…

Task	1	2	3	4	Please elaborate how if different
	very different than in airplane	moderately different	slightly different	the same as in airplane	
Engine cut at V_1					
Engine cut at V_R					
Engine-out straight-in approach/ldg					
Engine-out sidestep landing					

Pilot Performance

Compare your performance in the NASA 747-400 **simulator** to your performance in the B747-400 **airplane.**

After the break, my performance in the NASA747-400 simulator was...

Task	1	2	3	4	5	6	7
	much worse than in airplane	moderately worse	slightly worse	just like in the airplane	slightly better	moderately better	much better than in airplane
Engine cut at V_1							
Engine cut at V_R							
Engine-out straight-in approach/ldg							
Engine-out sidestep landing							
Please elaborate if different from performance in airplane							

Physical and Mental Workload

Compare the NASA 747-400 **simulator** to the B747-400 **airplane** in terms of the **physical and mental workload associated with performing the tasks.**

After the break, workload in the NASA 747-400 simulator was…

	1	2	3	4	5	6	7
Type of Workload	much higher than airplane	moderately higher	slightly higher	the same as airplane	slightly lower	moderately lower	much lower than airplane
Physical							
Please elaborate if physical workload is higher/lower than in the airplane							
Mental							
Please elaborate if mental workload is different than in the airplane							

Physical Comfort

Compare the NASA 747-400 **simulator** to the **last 747-400 SIMULATOR** you have flown in terms of the absence of nausea or simulator-induced disorientation.

After the break, my **physical comfort** in the NASA 747-400 simulator was...

	1	2	3	4	5	6	7
	much worse than in the last simulator	moderately worse	slightly worse	just like the last simulator	slightly better	moderately better	much better than in the last simulator
Overall comfort							
Please elaborate if comfort is different than in last simulator							

Acceptability

Compare the NASA 747-400 **simulator** to
the **last 747-400 SIMULATOR you have flown**
in terms of your **acceptance** based on your perception of the
presence or absence of deficiencies that might affect your flying.

After the break, acceptability of the NASA 747-400 simulator was...

	1	2	3	4	5	6	7
	much worse than last simulator flown	moderately worse	slightly worse	just like the last simulator flown	slightly better	moderately better	much better than last simulator flown
Overall acceptability							
Please elaborate if acceptability is different from last simulator							

Gaining Proficiency

Compare the **NASA 747-400** simulator to the last **747-400 SIMULATOR** you have flown in terms of the ease of gaining the proficiency necessary to perform satisfactorily in controlling the airplane.

After the break, I felt that **gaining proficiency** in the NASA simulator compared to the last simulator was…

	1	2	3	4	5	6	7
	much harder	moderately harder	slightly harder	just like in the last simulator	slightly easier	moderately easier	much easier
Overall gain of proficiency							

If different from last simulator, please elaborate which maneuvers mainly affect your judgment

- ❑ Engine cut at V_1
- ❑ Engine cut at V_R
- ❑ Engine-out straight-in approach/ldg
- ❑ Engine-out sidestep landing
- ❑ All of the above

PILOT FLYING – FINAL COMMENTS

General Information
Today's Date: ____________

Time: ____________

First Name: _________________ Last Name: ________________

Currently flying as a B-747-400 Captain ____First Officer____

Name of PNF during experiment: ______________________

Instructions:

Please feel free to add comments on your experiences in the simulator today and any other aspects related to the experiment as prompted on the following pages.

REMEMBER: Your opinion counts!

Further comments on the control feel, control sensitivity, and any other cues you experienced in the NASA 747-400 simulator compared to the B747-400 airplane:

Further comments on the handling qualities of the NASA 747-400 simulator and the strategies you used to control it compared to the B-747-400 airplane:

Further comments on your ability to gain proficiency in the NASA 747-400 simulator compared to the last 747-400 simulator you have flown:

____

Further comments on your physical comfort in the NASA 747-400 simulator compared to the last 747-400 simulator you have flown:

Further comments on the overall acceptability of the NASA 747-400 simulator:

Further comments on any other aspects of the experiment:

We greatly appreciate your expertise. You will receive a report on the conclusions from the experiment after completion of data collection and analysis.

APPENDIX 7. PILOT-NOT-FLYING QUESTIONNAIRES

PILOT NOT FLYING – QUESTIONNAIRE 1

General Information

Today's Date: _____________

Time: _____________

Name: _____________________

Name of PF during experiment: _______________________

Instructions for Questionnaires:

1. In these questionnaires you are asked to evaluate the performance of the **pilot flying (PF)**. Please compare the performance/workload of the PF to the performance/workload of an average PF performing the same maneuvers in the simulator. You may base "average" on any experiences you have had in trying out the maneuvers in the simulator, any past simulator experiences, and on the practical test standard guidelines.

2. Please base all of your judgments on the **maneuvers that the PF have flown so far.**

3. Please indicate each judgment by placing an **X** in the appropriate box. You may be asked to elaborate on your judgment in the space provided. Feel free to elaborate even if you are not specifically asked to do so.

Control Performance

Compare the performance of the **PF** to **average PF** in terms of the **precision in controlling the airplane to perform the required maneuvers**.

The performance of the PF in performing each maneuver was …..

Maneuver	1	2	3	4	5
	Unacceptable: Much worse than average	Unsatisfactory: Moderately worse than average	Satisfactory: The same as average	Good: Moderately better than average	Excellent: Much better than average
Engine cut at V_1					
Engine cut at V_R					
Engine-out straight-in approach/ldg					
Engine-out sidestep landing					

Control Strategy and Technique

Compare the PF to average PF
in terms of **how the PF flew the maneuvers and compensated for mechanical and weather disturbances,** i.e., whether the PF had to **adapt the sequence, amount,** and **type of controls he used.**

The **strategy and technique** of the PF to fly the maneuvers in the NASA 747-400 simulator was...

Maneuver	1 very different than average PF	2 moderately different	3 slightly different	4 the same as average PF	Please elaborate if different
Engine cut at V_1					
Engine cut at V_R					
Engine-out straight-in approach/ldg					
Engine-out sidestep landing					

Physical Workload

Compare the PF to average PF
in terms of the **physical workload** associated with flying the maneuvers.

Workload of the PF in the NASA 747-400 simulator was…

	1	2	3	4	5	6	7
Type of Workload	much higher than average PF	moderately higher	slightly higher	the same as average PF	slightly lower	moderately lower	much lower than average PF
Physical							
Please elaborate if physical workload is higher/lower than average PF							

PILOT NOT FLYING – QUESTIONNAIRE 2

General Information
Today's Date: _____________

Time: _____________

Name: _____________________

Name of PF during experiment: _______________________

Instructions for Questionnaires:

1. In these questionnaires you are asked to evaluate the performance of the **pilot flying (PF)**. Please compare the performance/workload of the PF to the performance/workload of an average PF performing the same maneuvers in the simulator. You may base "average" on any experiences you have had in trying out the maneuvers in the simulator, any past simulator experiences, and on the practical test standard guidelines.
2. Please answer all questions **based on the maneuvers that the PF have flown since Questionnaire 1**. Some questions are the same as in Questionnaire 1.
3. Please indicate each judgment by placing an **X** in the appropriate box. You may be asked to elaborate on your judgment in the space provided. Feel free to elaborate even if you are not specifically asked to do so.

Gaining Proficiency

Compare the **PF** to **average PF**
in terms of the **ease of gaining the proficiency**
necessary to perform satisfactorily in controlling the airplane.

During training, the **gaining proficiency** of the PF was…

	1	2	3	4	5	6	7
	much harder than average PF	moderately harder	slightly harder	just like average PF	slightly easier	moderately easier	much easier than average PF
Engine cut at V_1							
Engine cut at V_R							
Engine-out straight-in approach/ldg							
Engine-out sidestep landing							
Overall gain of proficiency							
Please elaborate if gaining proficiency is easier/harder than average PF							

Control Performance

Compare the performance of the **PF** to **average PF** in terms of the **precision in controlling the airplane to perform the required maneuvers**.

During training, the overall performance of the PF was …..

Maneuver	1	2	3	4	5
	Unacceptable: Much worse than average	Unsatisfactory: Moderately worse than average	Satisfactory: The same as average	Good: Moderately better than average	Excellent: Much better than average
Engine cut at V_1					
Engine cut at V_R					
Engine-out straight-in approach/ldg					
Engine-out sidestep landing					

Control Strategy and Technique

Compare the PF to average PF
in terms of **how the PF flew the maneuvers and compensated for mechanical and weather disturbances,** i.e., whether PF had to **adapt the sequence, amount,** and **type of controls he used.**

During training, the **strategy and technique** of the PF to fly the maneuvers in the NASA 747-400 simulator was...

	1	2	3	4
	very different than average PF	moderately different	slightly different	the same as average PF
Overall control strategy and technique				

If overall control strategy and technique are different from average PF, please indicate during which of the maneuvers and how

- ❑ Engine cut at V_1
- ❑ Engine cut at V_R
- ❑ Engine-out straight-in approach/ldg
- ❑ Engine-out sidestep landing
- ❑ All of the above

Physical Workload

Compare the PF to average PF
in terms of the **physical workload** associated with flying the maneuvers.

During training, **the physical workload of the PF** in the simulator was…

	1	2	3	4	5	6	7
Type of Workload	much higher than average PF	moderately higher	slightly higher	the same as average PF	slightly lower	moderately lower	much lower than average PF
Physical							
Please elaborate if physical workload is higher/lower than average PF							

PILOT NOT FLYING – QUESTIONNAIRE 3

General Information
Today's Date: _____________

Time: _____________

Name: _____________________

Name of PF during experiment: _______________________

Instructions for Questionnaires:

1. In these questionnaires you are asked to evaluate the performance of the **pilot flying (PF)**. Please compare the performance/workload of the PF to the performance/workload of an average PF performing the same maneuvers in the simulator. You may base "average" on any experiences you have had in trying out the maneuvers in the simulator, any past simulator experiences, and on the practical test standard guidelines.
2. Please answer all questions based on the maneuvers that the PF have flown after the break. Some questions are the same as in the previous questionnaires. This is to see whether you noticed any changes in the PF performance/workload in performing the last two scenarios in the simulator.
3. Please indicate each judgment by placing an **X** in the appropriate box. You may be asked to elaborate on your judgment in the space provided. Feel free to elaborate even if you are not specifically asked to do so.

Gaining Proficiency

Compare the **PF** to **average PF**
in terms of the **ease of gaining the proficiency**
necessary to perform satisfactorily in controlling the airplane.

After the break, the **gaining proficiency** of the PF was…

	1	2	3	4	5	6	7
	much harder than average PF	moderately harder	slightly harder	just like average PF	slightly easier	moderately easier	much easier than average PF
Engine cut at V_1							
Engine cut at V_R							
Engine-out straight-in approach/ldg							
Engine-out sidestep landing							
Overall gain of proficiency							
Please elaborate if gaining proficiency is easier/harder than average PF							

Control Performance

Compare the performance of the **PF** to **average PF**
in terms of the **precision in controlling the airplane to perform the required maneuvers**.

After the break, the overall performance of the PF was …..

Maneuver	1	2	3	4	5
	Unacceptable: Much worse than average	Unsatisfactory: Moderately worse than average	Satisfactory: The same as average	Good: Moderately better than average	Excellent: Much better than average
Engine cut at V_1					
Engine cut at V_R					
Engine-out straight-in approach/ldg					
Engine-out sidestep landing					

Control Strategy and Technique

Compare the PF to average PF
in terms of **how the PF flew the maneuvers and compensated for mechanical and weather disturbances,** i.e., **the sequence, amount,** and **type of controls the PF used.**

After the break, the **strategy and technique** of the PF to fly the maneuvers in the NASA 747-400 simulator was...

Tasks	1	2	3	4	Please elaborate if different
	very different than in airplane	moderately different	slightly different	the same as in airplane	
Engine cut at V_1					
Engine cut at V_R					
Engine-out straight-in approach/ldg					
Engine-out sidestep landing					

Physical Workload

Compare the PF to average PF
in terms of the **physical workload** associated with flying the maneuvers.

After the break, **the physical workload of the PF** in the simulator was…

	1	2	3	4	5	6	7
Type of Workload	much higher than average PF	moderately higher	slightly higher	the same as average PF	slightly lower	moderately lower	much lower than average PF
Physical							
Please elaborate if physical workload is higher/lower than average PF							

PILOT NOT FLYING – QUESTIONNAIRE 4

General Information
Today's Date: _____________

Time: _____________

Name: _____________________

Name of PF during experiment: _______________________

Instructions for Questionnaires:

4. In these questionnaires you are asked to evaluate the performance of the **pilot flying (PF)**. Please compare the performance/workload of the PF to the performance/workload of an average PF performing the same maneuvers in the simulator. You may base "average" on any experiences you have had in trying out the maneuvers in the simulator, any past simulator experiences, and on the practical test standard guidelines.
5. Please answer all questions based on the maneuvers that the PF have flown during the final scenarios. Some questions are the same as in the previous questionnaires. This is to see whether you noticed any changes in the PF performance/workload in performing the last two scenarios in the simulator.
6. Please indicate each judgment by placing an **X** in the appropriate box. You may be asked to elaborate on your judgment in the space provided. Feel free to elaborate even if you are not specifically asked to do so.

Gaining Proficiency

Compare the **PF** to **average PF**
in terms of the **ease of gaining the proficiency**
necessary to perform satisfactorily in controlling the airplane.

During the final scenarios, the **gaining proficiency** of the PF was…

	1	2	3	4	5	6	7
	much harder than average PF	moderately harder	slightly harder	just like average PF	slightly easier	moderately easier	much easier than average PF
Engine cut at V_1							
Engine cut at V_R							
Engine-out straight-in approach/ldg							
Engine-out sidestep landing							
Overall gain of proficiency							
Please elaborate if gaining proficiency is easier/harder than average PF							

Control Performance

Compare the performance of the **PF** to **average PF** in terms of the **precision in controlling the airplane to perform the required maneuvers**.

During the final scenarios, the overall performance of the PF was .....

Maneuver	1	2	3	4	5
	Unacceptable: Much worse than average	Unsatisfactory: Moderately worse than average	Satisfactory: The same as average	Good: Moderately better than average	Excellent: Much better than average
Engine cut at V_1					
Engine cut at V_R					
Engine-out straight-in approach/ldg					
Engine-out sidestep landing					

Control Strategy and Technique

Compare the PF to average PF
in terms of **how the PF flew the maneuvers and compensated for mechanical and weather disturbances,** i.e., **the sequence, amount,** and **type of controls the PF used.**

During the final scenarios, the **strategy and technique** of the PF to fly the maneuvers in the NASA 747-400 simulator was...

Tasks	1	2	3	4	Please elaborate if different
	very different than in airplane	moderately different	slightly different	the same as in airplane	
Engine cut at V_1					
Engine cut at V_R					
Engine-out straight-in approach/ldg					
Engine-out sidestep landing					

Physical Workload

Compare the PF to average PF
in terms of the **physical workload** associated with flying the maneuvers.

During the final scenarios, **the physical workload of the PF** in the simulator was…

	1	2	3	4	5	6	7
Type of Workload	much higher than average PF	moderately higher	slightly higher	the same as average PF	slightly lower	moderately lower	much lower than average PF
Physical							
Please elaborate if physical workload is higher/lower than average PF							

APPENDIX 8. LIST OF RECORDED SIMULATOR VARIABLES

Aircraft Motion

No.	*Variables*	*Unit*
1	Indicated Airspeed	knots
2	True Airspeed	knots
3	Ground Speed	knots
4	Vertical Speed	knots
5	Altitude	ft, MSL
6	Radar Altitude	ft, AGL
7	Rate Of Climb	ft/min
8	Pitch Attitude	degs
9	Pitch Rate, body axis	rad/s
10	Pitch Acceleration, body axis	rad/s^2
11	Roll Attitude	degs
12	Roll Rate, body axis	rad/s
13	Roll Acceleration, body axis	rad/s^2
14	Magnetic Heading	degs
15	True Heading	degs
16	Yaw Rate, body axis	rad/s
17	Yaw Acceleration, body axis	rad/s^2
18	Angle of Attack	degs
19	Angle of Sideslip	degs
20	X-body acceleration @ c.g., EOM	ft/s^2
21	Y-body acceleration @ c.g., EOM	ft/s^2
22	Z-body acceleration @ c.g., EOM	ft/s^2
23	Lateral Deviation (from initial position of aircraft)	ft
24	Ground Distance	ft
25	Longitude	degs
26	Latitude	degs

Aircraft Configuration

No.	*Variables*	*Unit*
1	Flap Position	degs
2	Spoiler Position	degs
3	Fuel Weight	lbs
4	c.g. location, w.r.t. aerodynamic center	%MAC
5	Engine 1 Failed Flag	T=failed
6	Engine 4 Failed Flag	T=failed
7	Engine 1 Thrust	lbs
8	Engine 2 Thrust	lbs
9	Engine 3 Thrust	lbs
10	Engine 4 Thrust	lbs
11	EPR 1	
12	EPR 2	
13	EPR 3	
14	EPR4	

No.	Variables	Unit
15	Weight On Wheel, Nose Flag	T=weight on
16	Weight On Wheel, Left Main Flag	T=weight on
17	Weight On Wheel, Right Main Flag	T=weight on
18	Rudder Trim Position	units
19	Aileron Trim Position	units
20	Elevator Trim Position	units
21	Elevator Position	degs
22	Aileron Position	degs
23	Rudder Position	degs
24	Landing Gear Selector Handle Position Flag	T=up

Pilot Response

No.	Variables	Unit
1	Column Position	inches
2	Wheel Position	degs
3	Pedal Position	inches
4	Column Rate	lbs
5	Wheel Rate	lbs
6	Pedal Rate	lbs
7	Power Lever Position	%
8	Applied Brake Pressure, Pilot Left	psi
9	Applied Brake Pressure, Pilot Right	psi
10	Applied Brake Pressure, Copilot Left	psi
11	Applied Brake Pressure, Copilot Right	psi
12	Brake Pedal Position, Pilot Left	inches
13	Brake Pedal Position, Pilot Right	inches
14	Brake Pedal Position, Copilot Left	inches
15	Brake Pedal Position, Copilot Right	inches

Simulator/Motion Drive

No.	Variables	Unit
1	Aural volume	%
2	X-body acceleration @ pilot station	ft/s^2
3	Y-body acceleration @ pilot station	ft/s^2
4	Z-body acceleration @ pilot station	ft/s^2
5	Translational motion command gain, X-body	
6	Translational motion command gain, Y-body	
7	Translational motion command gain, Z-body	
8	Roll motion command gain	
9	Pitch motion command gain	
10	Yaw motion command gain	
11	Scaled and limited translational motion command, X-body	ft/s^2
12	Scaled and limited translational motion command, Y-body	ft/s^2

No.	Variables	Unit
13	Scaled and limited translational motion command, Z-body	ft/s^2
14	Scaled and limited roll rate motion command	rad/s
15	Scaled and limited roll rate motion command	rad/s
16	Scaled and limited roll rate motion command	rad/s
17	Motion gain from the adaptive cost function, X-inertial	
18	Motion gain from the adaptive cost function, Y-inertial	
19	Motion gain from the adaptive cost function, Z-inertial	
20	Motion gain from the adaptive cost function, roll	
21	Motion gain from the adaptive cost function, pitch	
22	Motion gain from the adaptive cost function, yaw	
23	Roll attitude simulator command due to tilting	rad
24	Pitch attitude simulator command due to tilting	rad
25	Simulator translational displacement command, X-inertial	inch
26	Simulator translational displacement command, Y-inertial	inch
27	Simulator translational displacement command, Z-inertial	inch
28	Simulator angular displacement command, roll	degs
29	Simulator angular displacement command, pitch	degs
30	Simulator angular displacement command, yaw	degs
31	X-body acceleration @ pilot station, accelerometer	g
32	Y-body acceleration @ pilot station, accelerometer	g
33	Z-body acceleration @ pilot station, accelerometer	g
34	Roll rate body axis, rate gyro	rad/s^2
35	Pitch rate body axis, rate gyro	rad/s^2
36	Yaw rate body axis, rate gyro	rad/s^2
37	Roll attitude, potentiometer	degs
38	Pitch attitude, potentiometer	degs
39	Yaw attitude, potentiometer	degs
40	Actuator extension, leg 1	inches
41	Actuator extension, leg 2	inches
42	Actuator extension, leg 3	inches
43	Actuator extension, leg 4	inches
44	Actuator extension, leg 5	inches
45	Actuator extension, leg 6	inches

APPENDIX 9. LIST OF MEASURES CALCULATED PER SEGMENT

Engine Failure on Takeoff (V_1 cut and V_2 cut)

After Engine Failure to 800 ft AGL:

PERFORMANCE			
Type	**Variable**	**Measure**	**Description**
Directional	Yaw rate	Yaw Activity	Mean absolute yaw rate.
	Heading	STD Heading Deviation	Standard deviation of the deviation from the desired heading.
		RMS Heading Deviation	Root mean square of deviation from the desired heading.
		Maximum Heading Deviation	Maximum deviation from the desired heading.
		Average Heading Exceedance	Average of the absolute heading deviation exceeding 5° around the desired heading
		Average Failure Induced Heading	Integral of the heading deviation in the direction of the failed engine.
	Time	Pedal Reaction Time	Time for the pedal position to exit 0.75-inch band about its initial position in response to engine failure.
Lateral	Roll rate	Roll Activity	Mean absolute roll rate.
	Bank Angle	STD Bank Angle	Standard deviation of bank angle.
		RMS Bank Angle	Root mean square of bank angle
		Maximum Bank Angle	Maximum absolute bank angle.
		Average Bank Angle Exceedance	Average of the absolute bank angle outside of 5° band around wing level position.
		Average Failure Induced Bank Angle	Average of the absolute bank angle in the direction of the failed engine.
Longitudinal	Airspeed	Average Airspeed Exceedance	Average of absolute Indicated Airspeed deviation outside 5 knots band about V_2 (for V_1 cut) or about V_2+10 kts (for V_2 cut)
	Pitch Angle	STD Pitch Angle	Standard deviation of pitch angle.

Engine Failure on Takeoff (V_1 cut and V_2 cut)

After Engine Failure to 800 ft AGL:

WORKLOAD/BEHAVIOR			
Type	**Variable**	**Measure**	**Description**
Directional	Pedal position	RMS Pedal Response	Root mean square of pedal response, calculated by taking the square root of the total area under the pedal position power spectral density curve.
		STD Pedal Position	Standard deviation of pedal position.
		Pedal Response Bandwidth	Frequency below which the area under the pedal power spectral density curve constitutes 0.5 of total area.
		Pedal Reversals	The number of times the pedal position exits a 1-inch band centered at its neutral position after engine failure (20 s for V_1 cut and 10 s for V_2 cut).
Lateral	Wheel position	RMS Wheel Response	Root mean square of wheel response, calculated by taking the square root of the total area under the wheel position power spectral density curve.
		STD Wheel Position	Standard deviation of wheel position.
		Wheel Response Bandwidth	Frequency below which the area under the wheel power spectral density curve constitutes 0.5 of total area.
		Wheel Reversals	The number of times the wheel position exits a 10^{o} band centered at its neutral position after engine failure (20 s for V_1 cut and 10 s for V_2 cut).

WORKLOAD/BEHAVIOR			
Type	**Variable**	**Measure**	**Description**
Longitudinal	Column position	RMS Column Response	Root mean square of column position, calculated by taking the square root of the total area under the column power spectral density curve.
		STD Column Position	Standard deviation of column position.
		Column Response Bandwidth	Frequency below which the area under the column power spectral curve constitutes 0.5 of total area.
		Column Reversals	The number of times the column position exits a 4-inch band centered at its neutral position after engine failure (20 s for V_1 cut and 10 s for V_2 cut).

Precision Instrument Approach

From Final Approach-Fix to the Decision-Height (432 ft AGL/1020 ft MSL):

PERFORMANCE			
Type	**Variable**	**Measure**	**Description**
Directional	Yaw rate	Yaw Activity	Mean absolute yaw rate.
	Heading	STD Heading Deviation	Standard deviation of the deviation around the desired heading.
		Maximum Heading Deviation	Maximum deviation from the desired heading.
		Average Heading Exceedance	Average of the absolute deviation exceeding ±5° around the desired heading.
	Localizer Deviation	STD Localizer Deviation	Standard deviation of horizontal deviation of the airplane from the localizer centerline.
		Maximum Localizer Deviation	The maximum deviation of the airplane from the localizer centerline.
		Average Localizer Exceedance	Average of absolute deviation exceeding ±0.5 dot around localizer centerline.

PERFORMANCE			
Type	**Variable**	**Measure**	**Description**
Lateral	Roll rate	Roll Activity	Mean absolute roll rate.
	Bank Angle	STD Bank Angle	Standard deviation of bank angle.
		Maximum Bank Angle	Maximum absolute bank angle.
		Average Bank Angle Exceedance	Average of the absolute bank angle outside of ±5° band around wing level position.
Longitudinal	Airspeed	Average Airspeed Exceedance	Average of absolute deviation outside 5 knots band about the desired airspeed.
	Pitch Angle	STD Pitch Angle	Standard deviation of pitch angle.
	Glide Slope Deviation	STD Glide Slope Deviation	Standard deviation of vertical deviation from the glide slope reference path.
		Maximum Glide Slope Deviation	Maximum deviation from the glide slope reference path.
		Average Glide Slope Exceedance	Average of vertical deviation exceeding ±0.5 dot around the glide slope reference.

Precision Instrument Approach

From Final Approach-Fix to the Decision-Height (432 ft AGL/1020 ft MSL):

WORKLOAD/BEHAVIOR			
Type	**Variable**	**Measure**	**Description**
Directional	Pedal position	RMS Pedal Response	Root mean square of pedal response, calculated by taking the square root of the total area under the pedal power spectral density curve.
		STD Pedal Position	Standard deviation of pedal position.
		Pedal Response Bandwidth	Frequency below which the area under the pedal power spectral density curve constitutes 0.5 of total area.
		Pedal Reversals	The number of times the pedal position exits a 1-inch band centered at its neutral position during the first 70 s.

WORKLOAD/BEHAVIOR			
Type	**Variable**	**Measure**	**Description**
Lateral	Wheel position	RMS Wheel Response	Root mean square of wheel response, calculated by taking the square root of the total area under the wheel power spectral density curve.
		STD Wheel Position	Standard deviation of wheel position.
		Wheel Response Bandwidth	Frequency below which the area under the wheel power spectrum density curve constitutes 0.5 of total area.
		Wheel Reversals	The number of times the wheel position exits a 10º band centered at its neutral position during the first 70 s.
Longitudinal	Column position	RMS Column Response	Root mean square of column position, calculated by taking the square root of the total area under the column power spectral density curve.
		STD Column Position	Standard deviation of column position.
		Column Response Bandwidth	Frequency below which the area under the column power spectral curve constitutes 0.5 of total area.
		Column Reversals	The number of times the column position exits a 4-inch band centered at its neutral position during the first 70 s.

Precision Instrument Approach

From Decision-Height to Touchdown:

PERFORMANCE			
Type	**Variable**	**Measure**	**Description**
Directional	Yaw rate	Yaw Activity	Mean absolute yaw rate during the maneuver.
	Heading	STD Heading Deviation	Standard deviation of the deviation around the desired heading.
		Maximum Heading Deviation	Maximum deviation from the desired heading.
		Average Heading Exceedance	Average of the absolute deviation exceeding ±5° around the desired heading.
	Localizer Deviation	STD Localizer Deviation	Standard deviation of horizontal deviation of the airplane from the localizer centerline.
		Maximum Localizer Deviation	The maximum deviation of the airplane from the localizer centerline.
		Average Localizer Exceedance	Average of horizontal deviation exceeding ±0.5 dot around localizer centerline.
Lateral	Roll rate	Roll Activity	Mean absolute roll rate.
	Bank Angle	STD Bank Angle	Standard deviation of bank angle.
		Maximum Bank Angle	Maximum absolute bank angle.
		Average Bank Angle Exceedance	Average of the absolute bank angle outside of 5° band around wing level position.

PERFORMANCE			
Type	**Variable**	**Measure**	**Description**
Longitudinal	Airspeed	Average Airspeed Exceedance	Average of absolute deviation outside 5 knots about the desired airspeed.
		Touchdown Descent Rate	The initial vertical speed of the airplane at touchdown.
	Pitch Angle	STD Pitch Angle	Standard deviation of pitch angle.
	Glide Slope Deviation	STD Glide Slope Deviation	Standard deviation of vertical deviation from the glide slope reference path.
		Maximum Glide Slope Deviation	Maximum vertical deviation from the glide slope reference path.
		Average Glide Slope Exceedance	Average of vertical deviation exceeding ±0.5 dot around the glide slope reference.
	Distance	Touchdown Distance	Distance from runway threshold to the touchdown point.

Precision Instrument Approach

From Decision-Height to Touchdown:

WORKLOAD/BEHAVIOR			
Type	**Variable**	**Measure**	**Description**
Directional	Pedal position	RMS Pedal Response	Root mean square of pedal response, calculated by taking the square root of the total area under the pedal power spectral density curve.
		STD Pedal Position	Standard deviation of pedal position.
		Pedal Response Bandwidth	Frequency below which the area under the pedal power spectral density curve constitutes 0.5 of total area.
		Pedal Reversals	The number of times the pedal position exits a 1-inch band centered at its neutral position during the first 25 s.

WORKLOAD/BEHAVIOR			
Type	**Variable**	**Measure**	**Description**
Lateral	Wheel position	RMS Wheel Response	Root mean square of wheel response, calculated by taking the square root of the total area under the wheel power spectral density curve.
		STD Wheel Position	Standard deviation of wheel position.
		Wheel Response Bandwidth	Frequency below which the area under the wheel power spectral density curve constitutes 0.5 of total area.
		Wheel Reversals	The number of times the wheel position exits a 10º band centered at its neutral position during the first 25 s.
Longitudinal	Column position	RMS Column Response	Root mean square of column position, calculated by taking the square root of the total area under the column power spectral density curve.
		STD Column Position	Standard deviation of column position.
		Column Response Bandwidth	Frequency below which the area under the column power spectral curve constitutes 0.5 of total area.
		Column Reversals	The number of times the column position exits a 4-inch band centered at its neutral position during the first 25 s.

Sidestep Landing

From Final Approach-Fix to Breakout-of-Clouds (1688 ft MSL):

PERFORMANCE			
Type	**Variable**	**Measure**	**Description**
Directional	Yaw rate	Yaw Activity	Mean absolute yaw rate.
	Heading	STD Heading Deviation	Standard deviation of the deviation around the desired heading.
		Maximum Heading Deviation	Maximum deviation from the desired heading.
		Average Heading Exceedance	Average of the absolute deviation exceeding ±5° around the desired heading.
	Localizer Deviation	STD Localizer Deviation	Standard deviation of horizontal deviation of the airplane from the localizer centerline.
		Maximum Localizer Deviation	The maximum deviation of the airplane from the localizer centerline.
		Average Localizer Exceedance	Average of absolute deviation exceeding ±0.5 dot around localizer centerline.
Lateral	Roll rate	Roll Activity	Mean absolute roll rate.
	Bank Angle	STD Bank Angle	Standard deviation of bank angle.
		Maximum Bank Angle	Maximum absolute bank angle.
		Average Bank Angle Exceedance	Average of the absolute bank angle outside of ±5° band around wing level position.
Longitudinal	Airspeed	Average Airspeed Exceedance	Average of absolute deviation outside 5 knots band about the desired airspeed.
	Pitch Angle	STD Pitch Angle	Standard deviation of pitch angle.
	Glide Slope Deviation	STD Glide Slope Deviation	Standard deviation of vertical deviation from the glide slope reference path.
		Maximum Glide Slope Deviation	Maximum deviation from the glide slope reference path.
		Average Glide Slope Exceedance	Average of vertical deviation exceeding ±0.5 dot around the glide slope reference.

Sidestep Landing

From Final Approach-Fix to Breakout-of-Clouds (1688 ft MSL):

WORKLOAD/BEHAVIOR			
Type	**Variable**	**Measure**	**Description**
Directional	Pedal position	RMS Pedal Response	Root mean square of pedal response, calculated by taking the square root of the total area under the pedal power spectral density curve.
		STD Pedal Position	Standard deviation of pedal position.
		Pedal Response Bandwidth	Frequency below which the area under the pedal power spectral density curve constitutes 0.5 of total area.
		Pedal Reversals	The number of times the pedal position exits a 1-inch band centered at its neutral position during the last 20 s.
Lateral	Wheel position	RMS Wheel Response	Root mean square of wheel response, calculated by taking the square root of the total area under the wheel power spectral density curve.
		STD Wheel Position	Standard deviation of wheel position.
		Wheel Response Bandwidth	Frequency below which the area under the wheel power spectral density curve constitutes 0.5 of total area.
		Wheel Reversals	The number of times the wheel position exits a 10^{o} band centered at its neutral position during the last 20 s.

WORKLOAD/BEHAVIOR			
Type	**Variable**	**Measure**	**Description**
Longitudinal	Column position	RMS Column Response	Root mean square of column position, calculated by taking the square root of the total area under the column power spectral density curve.
		STD Column Position	Standard deviation of column position.
		Column Response Bandwidth	Frequency below which the area under the column power spectral curve constitutes 0.5 of total area.
		Column Reversals	The number of times the column position exits a 4-inch band centered at its neutral position during the last 20 s.

Sidestep Landing

From Breakout-of-Clouds to Upward-Gust:

Note: sidestep segment is defined from 800 ft to 200 ft to the left of target runway centerline.

PERFORMANCE			
Type	**Variable**	**Measure**	**Description**
Directional	Yaw rate	Yaw Activity	Mean absolute yaw rate .
	Heading	STD Heading Deviation	Standard deviation of the deviation from the desired heading.
		Maximum Heading Deviation	Maximum deviation from the desired heading.
		Maximum Sidestep Heading	Maximum deviation from desired heading in the sidestep segment.
		Average Heading Exceedance	Average of the heading deviation exceeding ±5^{o} around the desired heading.
	Localizer Deviation	Maximum Localizer Overshoot	Maximum deviation from the localizer centerline after sidestep.

PERFORMANCE			
Type	**Variable**	**Measure**	**Description**
Lateral	Roll rate	Roll Activity	Mean absolute roll rate.
	Bank Angle	STD Bank Angle	Standard deviation of bank angle.
		Maximum Bank Angle	Maximum absolute bank angle.
		Maximum Sidestep Bank Angle	Maximum absolute bank angle during sidestep.
		Average Bank Angle Exceedance	Average of the absolute bank angle outside of ±5° band around wing level position.
	Time	Sidestep Time	The time required to perform the sidestep maneuver.
	Translational rate	Sidestep Rate	Lateral translational rate to travel through the sidestep segment.
Longitudinal	Airspeed	Average Airspeed Exceedance	Average of absolute deviation outside 5 knots band about the desired airspeed.
	Pitch Rate	Pitch Activity	Mean absolute pitch rate after.
	Pitch Angle	STD Upset Pitch Angle	Standard deviation of pitch angle after the application of vertical gust.
	Glide Slope Deviation	STD Glide Slope Deviation	Standard deviation of vertical deviation from the glide slope reference path.
		Maximum Glide Slope Deviation	Maximum deviation from the glide slope reference path.
		Average Glide Slope Exceedance	Average of vertical deviation exceeding ±0.5 dot around the glide slope reference.

Sidestep Landing

From Breakout-of-Clouds to Upward-Gust:

WORKLOAD/BEHAVIOR			
Type	**Variable**	**Measure**	**Description**
Directional	Pedal position	RMS Pedal Response	Root mean square of pedal response, calculated by taking the square root of the total area under the pedal power spectral density curve.
		STD Pedal Position	Standard deviation of pedal position.
		Pedal Response Bandwidth	Frequency below which the area under the pedal power spectral density curve constitutes 0.5 of total area.
		Pedal Reversals	The number of times the pedal position exits a 1-inch band centered at its neutral position during the first 20 s.
Lateral	Wheel position	RMS Wheel Response	Root mean square of wheel response, calculated by taking the square root of the total area under the wheel power spectral density curve.
		STD Wheel Position	Standard deviation of wheel position.
		Wheel Response Bandwidth	Frequency below which the area under the wheel power spectral density curve constitutes 0.5 of total area.
		Wheel Reversals	The number of times the wheel position exits a 10^{o} band centered at its neutral position during the first 20 s.

WORKLOAD/BEHAVIOR			
Type	**Variable**	**Measure**	**Description**
Longitudinal	Column position	RMS Column Response	Root mean square of column position, calculated by taking the square root of the total area under the column power spectral density curve.
		STD Column Position	Standard deviation of column position.
		Column Response Bandwidth	Frequency below which the area under the column power spectral curve constitutes 0.5 of total area.
		Column Reversals	The number of times the column position exits a 4-inch band centered at its neutral position during the first 20 s.

Sidestep Landing

From Upward-Gust to Touchdown:

PERFORMANCE			
Type	**Variable**	**Measure**	**Description**
Directional	Yaw rate	Yaw Activity	Mean absolute yaw rate.
	Heading	STD Heading Deviation	Standard deviation of the deviation from the desired heading.
		Maximum Heading Deviation	Maximum deviation from the desired heading.
		Average Heading Exceedance	Average of the absolute deviation exceeding ±5^{o} around the desired heading.
	Localizer Deviation	STD Localizer Deviation	Standard deviation of horizontal deviation of the airplane from the localizer centerline.
		Maximum Localizer Deviation	The maximum deviation of the airplane from the localizer centerline.
		Average Localizer Exceedance	Average of horizontal deviation exceeding ±0.5 dot around localizer centerline.

PERFORMANCE			
Type	**Variable**	**Measure**	**Description**
Lateral	Roll rate	Roll Activity	Mean absolute roll rate.
	Bank Angle	STD Bank Angle	Standard deviation of bank angle.
		Maximum Bank Angle	Maximum absolute bank angle.
		Average Bank Angle Exceedance	Average of the absolute bank angle outside of ±5º band around wing level position.
Longitudinal	Airspeed	Average Airspeed Exceedance	Average of absolute deviation outside ±5 knots band about the desired airspeed.
		Touchdown Descent Rate	The initial vertical speed of the airplane at touchdown.
	Pitch Angle	STD Pitch Angle	Standard deviation of pitch angle during the maneuver.
	Glide Slope Deviation	STD Glide Slope Deviation	Standard deviation of vertical deviation from the glide slope reference path.
		Maximum Glide Slope Deviation	Maximum deviation from the glide slope reference path.
		Average Glide Slope Exceedance	Average of vertical deviation exceeding ±0.5 dot around the glide slope reference.
	Distance	Touchdown Distance	Distance from runway threshold to the touchdown point.

Sidestep landing

From Upward-Gust to Touchdown:

WORKLOAD/BEHAVIOR			
Type	**Variable**	**Measure**	**Description**
Directional	Pedal position	RMS Pedal Response	Root mean square of pedal response, calculated by taking the square root of the total area under the pedal power spectral density curve.
		STD Pedal Position	Standard deviation of pedal position.
		Pedal Response Bandwidth	Frequency below which the area under the pedal power spectrum density curve constitutes 0.5 of total area.
		Pedal Reversals	The number of times the pedal position exits a 1-inch band centered at its neutral position during the first 40 s.
Lateral	Wheel position	RMS Wheel Response	Root mean square of wheel response, calculated by taking the square root of the total area under the wheel power spectral density curve.
		STD Wheel Position	Standard deviation of wheel position.
		Wheel Response Bandwidth	Frequency below which the area under the wheel power spectral density curve constitutes 0.5 of total area.
		Wheel Reversals	The number of times the wheel position exits a 10^{o} band centered at its neutral position during the first 40 s.

WORKLOAD/BEHAVIOR			
Type	**Variable**	**Measure**	**Description**
Longitudinal	Column position	RMS Column Response	Root mean square of column position, calculated by taking the square root of the total area under the column power spectral density curve.
		STD Column Position	Standard deviation of column position.
		Column Response Bandwidth	Frequency below which the area under the column power spectral curve constitutes 0.5 of total area.
		Column Reversals	The number of times the column position exits a 4-inch band centered at its neutral position during the first 40 s.

APPENDIX 10. GRADING CRITERIA AND WEIGHTS

I. The Grade Scale

- Grade scale consists of five different levels
  - 5 = Excellent 4 = Good 3 = Average 2 = Poor 1 = Unacceptable

- Each grading criteria for each plot will receive one of these grades
  - These grades will be weighted based on the criteria to provide a weighted score for that particular plot

- Likewise, each plot will contribute this weighted score with its own weight to calculate the overall score for each of the four maneuvers

II. Things to know for grading

- Bad results such as Crash, Rejected Takeoff and missed approaches will all automatically receive the lowest possible score, which is 1

- Only deviations of two or more red data-point dots will be considered as out-of-bound deviations. A deviation of only one dot can be considered to have never deviated outside of the bounds. If there are only two red data points, the second read data point must not be on the boundary line to be considered an out of bound deviation.

- Likewise, a plot that only re-enters the in-bounds region for one data point, will only be counted as having one out of bound (OB) deviation and not 2

- On the approach glide-path deviation plot, the final three data point dots to the left of the 0 nm point will be ignored, regardless of its color.

III. Takeoff Heading Deviation Plot for both V_1 and V_2 Cut

- ➢ **Plot weighting for score of maneuver = .50**

1) The ability to stay in bounds **(Weight = .25)**
- 0 OB deviations results in a score of 5
- 1 OB deviation results in a score of 4
- 2 OB deviations result in a score of 3
- 3 OB deviations result in a score of 2
- 4 or more OB deviations result in a score of 1

2) Length of out of bounds deviation **(Weight = .25)**
- A total deviation length of 0 nm results in a score of 5
- A total deviation length between 0 – 0.5 nm results in a score of 4
- A total deviation length between 0.5 and 1.0 nm results in a score of 3
- A total deviation length greater than 1.0 nm results in a score of 1

3) Magnitude of out of bounds deviation **(Weight = .25)**
- A maximum deviation less than 5 degrees results in a score of 5

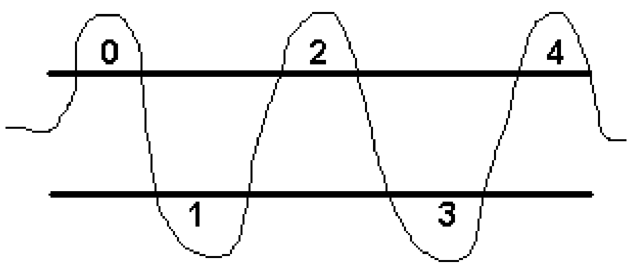
- A maximum deviation between 5 and 7.5 degrees results in a score of 4
- A maximum deviation between 7.5 and 10 degrees results in a score of 3
- A maximum deviation greater than 10 degrees results in a score of 1

4) Location of out of bounds deviation **(Weight = .10)**

- A plot with no deviations will result in a score of 5
- A plot with deviation only within 0.5 nm will result in a score of 4
- Any deviations that occurs from 0.5 to 1.5 nm after engine failure will result in a score of 3
- Any deviations that occurs beyond 1.5 nm after engine failure will result in a score of 1

5) Steadiness (reversals) **(Weight = .15)**

- A plot with no reversals will result in a score of 5
- Any plot with one reversal will result in a score of 3
- Any plot with two reversals will result in a score of 2
- Any plot with three or more reversals will result in a score of 1



- (See below graph for how to determine the # of reversals)

IV. Takeoff Airspeed Deviation Plot for both V_1 and V_2 Cut

- **Plot weighting for score of maneuver = .10**

1) Attempt at maintaining speed within bounds

- Any plot with 0 deviations will result in a score of 5
- Any plot where it is apparent there was an attempt to try to maintain speed within the boundaries will result in a score of 4
- Any plot where the speed boundaries were clearly ignored will result in a score of 3

V. Takeoff Altitude Deviation Plot for both V_1 and V_2 Cut

- This plot will not receive any grading due to the following factors
  - Extreme similarity of the plots
  - Lack of appropriate criteria to determine performance
  - No instruction given to pilots in regard to this plot

VI. Takeoff Bank Angle Plot for both V_1 and V_2 Cut

- **Plot weighting for score of maneuver = .40**

1) The ability to stay in bounds **(Weight = .20)**
- 0 OB deviations results in a score of 5
- 1 OB deviation results in a score of 4
- 2 OB deviations result in a score of 3
- 3 OB deviations result in a score of 2
- 4 or more OB deviations result in a score of 1

2) Length of out of bounds deviation **(Weight = .15)**
- A total deviation length of 0 nm results in a score of 5
- A total deviation length between 0 – 0.5 nm results in a score of 4
- A total deviation length between 0.5 and 1.0 nm results in a score of 3
- A total deviation length greater than 1.0 nm results in a score of 1

3) Magnitude of out of bounds deviation **(Weight = .20)**
- A maximum deviation less than 5 degrees results in a score of 5
- A maximum deviation between 5 and 7.5 degrees results in a score of 4
- A maximum deviation between 7.5 and 10 degrees results in a score of 3
- A maximum deviation of only one red data dot will result in a score of 2
- A maximum deviation greater than 10 degrees results in a score of 1

4) Location of out of bounds deviation **(Weight = .15)**
- A plot with no deviations will result in a score of 5
- The first deviation as result of the engine failure will be ignored, unless that deviation >10 degrees (even for just one dot), in that case 1 point will be subtracted from the location score (1 is still the lowest possible score)
- Any deviations that occurs from 0.5 to 1 nm after engine failure will result in a score of 1
- Any deviations that occurs beyond 1 nm after engine failure will result in a score of 3
- Examples:
  - A plot with only one dot deviation >10 degrees that is the first deviation from the engine failure will receive a score of 4 because of the subtraction…. Had this first deviation not >10 degrees, the score would be 5
  - A plot with a first deviation >10 degrees and a second deviation 1 nm after engine failure will receive a score of 2. (3 - 1 = 2)

5) Steadiness (reversals) – determined as in heading **(Weight = .20)**
- A plot with no reversals will result in a score of 5
- Any plot with one reversal will result in a score of 3
- Any plot with two reversals will result in a score of 2
- Any plot with three or more reversals will result in a score of 1

6) Bank Direction **(Weight = .10)**
- A plot that if 0.5 nm after the engine failure it is apparent the tendency of the pilot was to try to maintain a bank towards the good engine will result in a score of 5

- A plot that if 0.5 nm after the engine failure it is unclear what the tendency of the pilot was (switched often between bank to the good engine and bank to bad engine) will result in a score of 3
- A plot that if 0.5 nm after the engine failure it is apparent the pilot was not trying to maintain a bank towards the good engine, but instead favored the bad engine will result in a score of 1

VII. Approach Glide-Path Deviation Plot for both PIA and SSL

- **Plot weighting for score of maneuver = .40 for PIA and .50 for SSL**

VII (Note that the last three data points before 0 nm are ignored)

VIII 1) The ability to stay in bounds **(Weight = .25)**
- 0 OB deviations results in a score of 5
- 1 OB deviation results in a score of 4
- 2 OB deviations result in a score of 3
- 3 OB deviations result in a score of 2
- 4 or more OB deviations result in a score of 1

2) Length of out of bounds deviation **(Weight = .25)**
- A total deviation length of 0 nm results in a score of 5
- A total deviation length between 0 – 0.5 nm results in a score of 4
- A total deviation length between 0.5 and 1.0 nm results in a score of 3
- A total deviation length greater than 1.0 nm results in a score of 1

3) Magnitude of out of bounds deviation **(Weight = .25)**
- A maximum deviation staying within one dot results in a score of 5
- A maximum deviation between plus/minus 1.5 dot results in a score of 4
- A maximum deviation between plus/minus two dot results in a score of 3
- A maximum deviation greater than 2 DOT results in a score of 1

4) Location of out of bounds deviation **(Weight = .15)**
- A plot with no deviations will result in a score of 5
- A plot with only deviations less than +/- 2 dot between 2 – 0 nm will receive a score of 4
- Any deviations that occur from 4 to 2 nm will result in a score of 3
- Any deviations that occur beyond 2 nm that is greater than +/- 2 dot will result in a score of 1

5) Steadiness (reversals) – determined same as previous **(Weight = .10)**
- A plot with no reversals will result in a score of 5
- Any plot with one reversal will result in a score of 3
- Any plot with two or more reversals will result in a score of 1

VIII. Approach Localizer Deviation Plot for PIA

- **Plot weighting for score of maneuver = .40**

IX 1) The ability to stay in bounds **(Weight = .25)**

- 0 OB deviations results in a score of 5
- 1 OB deviation results in a score of 3
- 2 OB deviations result in a score of 2
- 3 or more OB deviations result in a score of 1

2) Length of out of bounds deviation **(Weight = .25)**
- A total deviation length of 0 nm results in a score of 5
- A total deviation length between 0 – 0.5 nm results in a score of 3
- A total deviation length between 0.5 and 1.0 nm results in a score of 2
- A total deviation length greater than 1.0 nm results in a score of 1

3) Magnitude of out of bounds deviation **(Weight = .25)**
- A plot with no deviations will result in a score of 5
- A maximum deviation that does not have two or more data points in a straight line at the limit of the plot (top and bottom will result in a score of 3
- A maximum deviation that has two or more data points in a straight line at the limit of the plot (top and bottom) will result in a score of 1

4) Location of out of bounds deviation **(Weight = .15)**
- A plot with no deviations will result in a score of 5
- Any deviations that occur from 4 to 2 nm will result in a score of 3
- Any deviations that occurs beyond 2 nm will result in a score of 1

5) Steadiness (reversals) – determined same as previous **(Weight = .10)**
- A plot with no reversals will result in a score of 5
- Any plot with one reversal will result in a score of 3
- Any plot with two or more reversals will result in a score of 1

IX. Approach Localizer Deviation Plot for SSL

- **Plot weighting for score of maneuver = .30**

X 1) The ability to stay in bounds **(Weight = .25)**
- 0 OB deviations results in a score of 5
- 1 OB deviation results in a score of 3
- 2 OB deviations result in a score of 2
- 3 or more OB deviations result in a score of 1

2) Length of out of bounds deviation **(Weight = .25)**
- A total deviation length of 0 nm results in a score of 5
- A total deviation length between 0 – 0.5 nm results in a score of 3
- A total deviation length between 0.5 and 1.0 nm results in a score of 2
- A total deviation length greater than 1.0 nm results in a score of 1

3) Magnitude of out of bounds deviation **(Weight = .25)**
- A plot with no deviations will result in a score of 5
- A maximum deviation that does not have two or more data points in a straight line at the limit of the plot (top and bottom will result in a score of 3
- A maximum deviation that has two or more data points in a straight line at the limit of the plot (top and bottom) will result in a score of 1

4) Location of entry into one dot after Sidestep **(Weight = .15)**

- A plot that enters the one-dot region before 1.5 nm to go before the runway will result in a score of 5
- A plot that enters the one-dot region before 1.5 nm but then deviates OB before 1 nm will result in a score of 3
- A plot that enters the one-dot region before 1.5 nm but then deviates OB after 1 nm will result in a score of 1.
- A plot that enters the one-dot region between 1.5 and 1.0 nm before the runway will result in a score of 3
- A plot that enters the one-dot region after 1.0 nm before the runway will result in a score of 1

5) Steadiness (reversals) – determined same as previous **(Weight = .10)**
- A plot with no reversals will result in a score of 5
- Any plot with one reversal will result in a score of 3
- Any plot with two or more reversals will result in a score of 1

X. Approach Airspeed Deviation Plot for both PIA and SSL

- **Plot weighting for score of maneuver = .20**

1) The ability to stay in bounds **(Weight = .25)**
- 0 OB deviations results in a score of 5
- 1 OB deviation results in a score of 4
- 2 OB deviations result in a score of 3
- 3 OB deviations result in a score of 2
- 4 or more OB deviations result in a score of 1

2) Length of out of bounds deviation **(Weight = .25)**
- A total deviation length of 0 nm results in a score of 5
- A total deviation length between 0 – 0.5 nm results in a score of 4
- A total deviation length between 0.5 and 1.0 nm results in a score of 3
- A total deviation length greater than 1.0 nm results in a score of 1

3) Magnitude of out of bounds deviation **(Weight = .20)**
- A maximum deviation staying within 10 results in a score of 5
- A maximum deviation staying between 10 –15 results in a score of 4
- A maximum deviation between 15 – 20 results in a score of 3
- A maximum deviation greater than 20 results in a score of 1

4) Location of out of bounds deviation **(Weight = .20)**
- A plot with no deviations will result in a score of 5
- Any deviations that occurs from 4 to 1 nm will result in a score of 3
- Any deviations that occurs beyond 1 nm will result in a score of 1

5) Steadiness (reversals) – determined same as previous **(Weight = .10)**
- A plot with no reversals will result in a score of 5
- Any plot with one reversal will result in a score of 2
- Any plot with two or more reversals will result in a score of 1

APPENDIX 11. COMMENTS ON MOTION BY NO-MOTION GROUP[6]

PF	Questionnaire	Question	Subquestion	Comment
NM-01	1	other cues	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Not as much motion visual cue's [sic]
NM-01	1	physical comfort		I do not have problems with simulator-induced disorientation but the sim motion was not rough enough. It is hard to say if this perception is from other sims or the airplane. Because the engine out work is in the sim.
NM-01	2	acceptability		The motion is less then [sic] the [company] sim. The [company] sim motion is greater at times then [sic] than the A/C. Of course both sim [sic] can not reproduce the feel of some maneuvers. But the [company] sim over compasates [sic] for lack of visual cue's [sic] with too much motion.
NM-01	2	control strategy and technique	engine cut at V1; engine cut at VR	In A/C it is apperent [sic] which engine had [sic] failed. I would take a 100% rudder input and leave it for the 1st segmet [sic] of the manover [sic]. Here in this sim I had to constantly scan the yaw indicator.
NM-01	2	gaining proficiency	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	A/C flies like 767 sim, which differs to all other [sic], ie. rudder, yaw indicator is not dampand [sic]. Seems to not want to stay in steady state. The sim makes one work harder. For some reason the feel as to which engine has failed is not as good. The sim also feels as though the motion is off making the ID of engine fail [sic] difficult
NM-01	2	mental workload		Less visual cue's [sic] and less motion.
NM-01	2	other cues	engine cut at V1; engine cut at VR	There seemed to be less motion
NM-01	2	other cues	engine-out straight-in approach/landing; engine-out sidestep landing	I was not sure the motion was on
NM-01	2	physical comfort		I can not be certian [sic] the motion was on.
NM-01	4	control feel, control sensitivity, and any other cues		I think the simulator motion input was increased on the last 2 periods. ELV [elevator] feel was difficult to estimate. The trim made no noise when running.

[6] Note that pilot NM-09 was excluded from all analyses because it was discovered only after his participation that he was not currently qualified on the B747-400 airplane. He was replaced by NM-21.

PF	Questionnaire	Question	Subquestion	Comment
NM-02	2	other cues	engine cut at V1; engine cut at VR	PROBABLY BETTER YAW feel in aircraft when you would lose an engine?
NM-02	3	other cues	engine cut at V1; engine cut at VR	Engine cuts - hard to feel the yaw.
NM-02	4	control feel, control sensitivity, and any other cues		Simulator is a little rough sometimes when you make aggressive inputs-the airplane is not quite as rough Throttles were a little sensitive - - maybe aircraft (simulator was light) Elevator was still a little heavy in light turbulence
NM-04	1	acceptability		Feel, response + visuals would be 3-4, but the lack of accurate motion falls in the "1" category.
NM-04	1	other cues	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Motion response to an [sic] control inputs were non-existant [sic], particularly on large scale events/ inputs. (Eng. failures, landing, rapid control inputs)
NM-04	1	physical comfort		Not better or worse, but the motion fidelity is not at all like other sims. Motion cues seemed non-existant [sic] throughout this session. Visual picture on landing roll seemed to appear "lower" to ground than normal.
NM-04	2	other cues	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Again motion was ineffective as a cue for any maneuvers.
NM-04	2	physical comfort		Lack of accurate motion ques [sic] had no effect on my comfort.
NM-04	2	physical workload; mental workload		Increased workload due to degrades , increased monitoring of basic control parameters. Trimming yaw is useless.
NM-04	3	other cues	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Can only compare to other sims. Never did any of these maneuvers in airplane. Exagerated [sic] yaw sensitivity resulted in excessive movement cues (transitory).
NM-04	3	physical comfort		Excessive yaw sensitivities create excessive motions. It appears motions in all axes reflect what sim is doing however.

PF	Questionnaire	Question	Subquestion	Comment
NM-04	4	control feel, control sensitivity, and any other cues		Feel in all axes of control seem slightly lighter than normal. Control sensitivity in pitch + roll seem slightly higher than normal, but this may be explained by lighter gross weights used in the scenario. Control sensitivity in yaw is much higher than normal. Based on control movements (rudder or aileron through adverse yaw), trim effects or asymetric [sic] thrust. It was very difficult to make subtle changes without over controlling, even with practice. Motion cues varied throughout the day, with motion cues being imperceptible in first 2 sessions. Overall fidelity of sim is directly proportional to motion.
NM-04	4	physical comfort		With the motion dialed up, the excessive yaw sensitivity leads to some pretty big motion transients, which I believe are exagerated [sic]. This could create some discomfort.
NM-05	2	acceptability		Little ground feel.
NM-05	2	control sensitivity	yaw control	No feel.
NM-05	2	control sensitivity	yaw control; roll control; pitch control; throttle control	Don't feel motion in sim.
NM-05	2	other cues	engine cut at V1; engine cut at VR	No feel.
NM-05	2	other cues	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	No ground feel. Only indicaton [sic] of landing is spoiler.
NM-05	3	other cues	engine cut at V1; engine cut at VR	Unable to simulate exact motion of aircraft.
NM-05	4	acceptability		Very good simulator. Better with motion on, though
NM-06	1	other cues	engine cut at V1	Airplane will give cues (feel, noise.) Normal.
NM-06	1	other cues	engine cut at VR	Airplane will give you cues (feel/noise) More cues in airplane.
NM-06	2	other cues	engine cut at V1; engine cut at VR	No external cues - No noise. No feeling. The only thing that’s telling me what the aircraft is doing is the flight instruments.
NM-06	2	other cues	engine-out straight-in approach/landing	No feel at touchdown.

PF	Questionnaire	Question	Subquestion	Comment
NM-06	3	other cues	engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	I would have cues in the airplane [like] seat of the pants.
NM-06	3	pilot performance	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	[Slightly worse] because of lack of cues.
NM-07	1	acceptability		Very little or no motion felt.
NM-07	1	control strategy and technique	engine cut at VR	Because no motion was felt throughout flight
NM-07	1	handling qualities	bank angle control; yaw control; altitude control; overall handling qualities	Felt almost no motion
NM-07	1	mental workload		Had to rely much more on instruments because of lack of motion in sim.
NM-07	1	other cues	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Very little motion felt if any.
NM-07	1	pilot performance	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Very little motion or no motion felt in sim.
NM-07	2	acceptability		Would have been just like the sim. in [company simulator facility] except for motion and perhaps a more sensitive rudder.
NM-07	2	control strategy and technique	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	No Motion Felt
NM-07	2	gaining proficiency	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Needs more motion to accurately simulate A/C.

PF	Questionnaire	Question	Subquestion	Comment
NM-07	2	mental workload		Have to rely more on instruments because of lack of motion/ A/C feel.
NM-07	2	other cues	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	No Motion Felt
NM-07	3	other cues	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Motion appeared to be on and functioning properly this session
NM-07	4	gaining proficiency		Able to gain proficiency faster flying with the motion on. Less mental workload. Reduced reliance on instruments.
NM-08	2	other cues	engine cut at V1; engine cut at VR	Did not feel yaw
NM-08	4	control feel, control sensitivity, and any other cues		Overall feel of sim is very similar to the airplane. I found it somewhat more sensitive in pitch than the airplane. Visual system is very good
NM-10	1	control feel	overall control feel	Overall control feel - seemed sensitive. Pitch and yaw primarily seemed lighter. It also seemed light. The motion was off. Not much seat of the pants especially on landing.
NM-10	3	control feel	rudder input; elevator input; throttles; overall control feel	Rudder input - in terms of feel, in this period I had more recognition of rudder "feel". It was slightly heavier than what I would expect in the a/c. Elevator input - was slightly heavier as I noticed on rotation and level off. Throttles - seemed more sensitive than the actual a/c. The power reference points seemed further back and they were sensitive in terms of corrective responses.
NM-10	4	control feel, control sensitivity, and any other cues		The last period seemed a bit more pitch sensitive. In the afternoon I could hear and feel the landings whereas in the morning period I did not. I did not feel as funky in the very last event set. The noise was more noticeable/audible in the afternoon set.
NM-10	4	handling qualities and control strategies		The tactile feel seemed different from the morning to the afternoon sets. The afternoon sets had more tactile feel.
NM-11	1	other cues	engine cut at VR	No "G" changes, of course. I think yaw sensation in aircraft would be much stronger

PF	Questionnaire	Question	Subquestion	Comment
NM-11	3	other cues	engine-out straight-in approach/landing; engine-out sidestep landing	The reaction to the shear was significant. The sim seemed to lurch/pitch
NM-13	3	handling qualities	bank angle control; yaw control; airspeed control; overall handling qualities	Don't feel as if--->After 3-4 hours in the sim, I have a "feel" for the sim. "Feels" like a/c very responsive to every input, but not overly sensitive.
NM-13	4	physical comfort		Sim felt like it "free flowed" a lot more. Could make for some uneasy stomachs.
NM-14	1	acceptability		My last simulator ride was more closely approximating the feel of the airplane. It felt heavier and more stable.
NM-14	1	handling qualities	yaw control; overall handling qualities	Again the yaw was much different. Also part of the problem might be that without the motion, you lose a large source of sensory information.
NM-14	1	other cues	engine cut at V1	No feeling due to no motion in sim. The engine cut was silent and harder to detect.
NM-14	1	other cues	engine cut at VR	Easier [than V1] to detect because the pilot has transitioned his scan to inside the a/c. [Pilot said VR was still different than the airplane because of lack of motion and sound.]
NM-14	1	pilot performance	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Harder to detect the engine failures which slowed down the response times. No motion and sound contributed to the quality of performance. Also on the sidestep procedure we had a slight wind sheer [sic] situation which resulted in us remaining high. This was not expected by the weather reports.
NM-14	2	other cues	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	In all situations there were less clues or cues to help identify the malfunction. -(Yaw- lack of feeling, when in the side-step procedure the windsheer [sic] is very smooth and you dont [sic] notice the airspeed green arrow increasing right away. What you first notice is the glide slope falling away. "lack of descent".
NM-14	3	other cues	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	With the addition of simulator motion there were more cues to help identify the malfunctions. It was helpful in all of the sequences. However the sim was still a little more tame than the airplane.

PF	Questionnaire	Question	Subquestion	Comment
NM-14	4	control feel, control sensitivity, and any other cues		This felt the most like the airplane. The cues provided helped identify the malfunctions. The controls felt heavy as they do in the airplane. Trimming is done more to releive [sic] control pressure than to maintain desired attitude. Without proper trimming the sim and plane feel very heavy making it uncomfortable.
NM-16	1	control sensitivity	yaw control; pitch control; overall control sensitivity	Again, because yaw inputs on the line tend to be minor, it is difficult to judge the sensitivity. Based only on instrument feedback, the yaw response seemed quite sensitive for the amount of rudder deflection. The aircraft gives much more physical feedback of yaw motion.
NM-16	1	handling qualities	pitch control; bank angle control; yaw control; altitude control; overall handling qualities	Lack of motion feeback [sic] makes performing tasks require greater concentration than the airplane. The simulator tends to seem less stable than the airplane. That may be as much a function of pilot over control due to lack of sensory input (ie. motion/sound)
NM-16	1	mental workload		When the flight path deviates from my target (speed, attitude etc.), I had to rely purely on my scan to detect it. There is little other input that you normally get in the a/c. I.E. changes in sound, sense of motion, etc.
NM-16	1	other cues	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	No Motion Sensation
NM-16	1	pilot performance	engine-out straight-in approach/landing; engine-out sidestep landing	During straight approach, I felt I was chasing needles. Lack of motion sensation put me behind and I had to try to consciously speed up my scan.
NM-16	2	acceptability		Only in the lack of motion.
NM-16	2	control strategy and technique	engine-out straight-in approach/landing; engine-out sidestep landing	On both I used less trim (elevator and rudder) because trim changes were hard to feel and created momentary instability. It was easier to trim approximately, then hand fly corrections. The a/c is much easier to trim.
NM-16	2	gaining proficiency	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Almost identical feel, however lack of motion makes gaining proficiency more difficult

PF	Questionnaire	Question	Subquestion	Comment
NM-16	2	handling qualities	pitch control; yaw control	The lack of motion is a distraction. It takes away from the sensation of flight. The simulator definitely lacks the stability of the a/c. The slightest force on the controls causes often unwanted attitude changes however slight.
NM-16	2	mental workload		You have to constantly focus on your instruments to maintain desired attitude. The simulator feels less stable and ther [sic] is less other feedback to detect changes in attitude/ airspeed.
NM-16	2	other cues	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	In all cases, small changes in attitude are difficult to detect by feel in the simulator like they can be in the aircraft. Sound in the a/c is also a help. You can hear very subtle changes in air noise in the a/c. You can also feel changes in speed in the aircraft.
NM-16	3	mental workload		Higher concentration required due to less cues as to changing airspeed or attitude. Also sim seems less stable.
NM-16	4	acceptability		Other than the slightly unusual feel of the motion, the NASA sim was on par with other sims I've flown. All are acceptable for preparing fo [sic] initial operating flights in the a/c.
NM-16	4	gaining proficiency		The last session was a bit unproductive as the motion felt unusual. The upside was that I gained confidence in my ability to ignore sensations which conflicted with my instrument indications.
NM-17	1	control strategy and technique	engine-out straight-in approach/landing	Power changes and subsequent yaw changes do not give the same physical feel in the seat of the pants.
NM-17	1	physical comfort		Less pitch and roll swing effect seemed to offer less disorientation.
NM-17	1	physical workload		Especially in yaw imput [sic]. The sim requires more imput [sic] because of lack of subtle seat of the pants cues. If those cues were present much finer and more frequent adjustments can be made.
NM-17	1	pilot performance	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	The seat of the pants physical cues and 3-D visual cues on breakout give a better feel for correction of errors. These added two cues help me refine what my instruments are telling me.

PF	Questionnaire	Question	Subquestion	Comment
NM-17	3	control strategy and technique	engine cut at VR	Without seat of pants cues correct the integration of instrument info was more difficult. [experimenter comment: motion was on during this phase]
NM-17	3	mental workload		Interpretation of instrument info during Vr cut/windshear scenario was hampered by reduced physical cues.
NM-17	3	other cues	engine cut at VR	Seat of the pants cues were off.
NM-17	3	other cues	engine-out straight-in approach/landing; engine-out sidestep landing	Wheel touchdown feel was better so I was better able to judge my flare on the 2nd approach and maintained better directional control throughout landing roll.
NM-17	3	pilot performance	engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Seat of the pants feel still lacking somewhat. Especially on Vr cut and windshear scenario. Felt my body would give me cues to assist me in instrument interpretation.
NM-18	1	acceptability		Too smooth & I didn't sense much yaw
NM-18	1	other cues	engine cut at V1; engine cut at VR	Lack of good yaw sense made manuever (sic) less accurate.
NM-18	1	other cues	engine-out straight-in approach/landing	Not much (air) feel. Bumps etc.
NM-18	2	control feel	rudder input; aileron input; elevator input; throttles; yaw trim input; roll trim input; pitch trim input	Seems like motion is off many times.
NM-18	2	control sensitivity	yaw control	Again to [sic] soft, hardly feel the rudder input
NM-18	2	control sensitivity	roll control	Again to [sic] soft, hardly feel the rudder input Should be more abrupt movement of ailerons with flaps >25
NM-18	2	gaining proficiency	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing;	Motion in yaw & pitch axis too smooth
NM-18	2	handling qualities	yaw control	Too nice. I can't feel the tail move (skid)
NM-18	2	other cues	engine cut at V1; engine cut at VR	Cant [sic] feel the bumps on runway. Also yaw was not perceptible.
NM-18	2	other cues	engine-out straight-in approach/landing	Cant [sic] feel the bumps in the air. (Turb)
NM-18	2	other cues	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	The motion was not perceptible during many of these manuevers [sic].
NM-18	3	acceptability		Not sure now what is accurate to the acft feel.

PF	Questionnaire	Question	Subquestion	Comment
NM-18	3	control strategy and technique	engine-out straight-in approach/landing	Still didn't notice WShear.
NM-18	3	control strategy and technique	engine-out sidestep Landing	More bumps needed (Turb)
NM-18	3	gaining proficiency	engine cut at V1; engine cut at VR	Over controlled the rudder (seat of pants) sensation of yaw is not dependable
NM-18	3	other cues	engine-out straight-in approach/landing	More bumps! & turb
NM-18	3	physical workload		More concentration required. Cant [sic] depend on senses!
NM-19	1	other cues	engine cut at V1; engine cut at VR	I expected greater yaw at eng failure
NM-19	1	pilot performance	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Couldn't seem to pick up cues - Visual seemed ok but feel was less than I expected (mainly yaw) for V1 VR cuts. Sidestep was ok but I didn't get the usual cues from crosswind I'm used to--seemed that drift perception was subdued somewhat.
NM-19	3	acceptability		More responsive in some controls and better cues. Seems more stable in roll/pitch
NM-19	3	mental workload		Both about the same - maybe a little easier mentally/ physically in sim due to improved cues. (I'm beat - hard to tell)
NM-19	4	acceptability		Certainly as acceptable as any other sim I've used. (With comments previously stated concerning slightly better stability, better cues, and somewhat greater control sensitivity.
NM-20	1	handling qualities	yaw control; heading control; overall handling qualities	The sim is a little harder to control heading because of yaw/rudder sensitivity + lack of seat of pants yaw feel
NM-20	1	other cues	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Lack of yaw feel
NM-20	1	pilot performance	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	With the nose up + few vis[ual] references the lack of yaw feel + extra sensitivity makes the VR cut harder in the sim. The V1 cut w/ center line info makes the yaw easier to solve on V1 cut + approaches
NM-20	2	other cues	engine cut at V1; engine cut at VR	Lack of seat of pants yaw

PF	Questionnaire	Question	Subquestion	Comment
NM-20	3	control strategy and technique	engine cut at V1; engine cut at VR	Somewhat easier in the A/C Seat of pants yaw
NM-20	3	gaining proficiency	engine cut at VR	Felt like it was harder to get yaw cues on this VR cut
NM-21	1	acceptability		Need that motion. Flight director would be nice
NM-21	1	control feel	rudder input; aileron input; elevator input; pitch trim input; overall control feel	Feels lighter, possibly due to motion off, or lighter gross weight than I normally use in the sim
NM-21	1	handling qualities	pitch control; bank angle control; yaw control; altitude control; heading control; overall handling qualities	Motion off is disorienting and reduces feedback. My head was almost spinning once breaking out on the ILS
NM-21	1	physical workload		Lack of flight directors, FPV's and motion made it more difficult. Also, slip indicator seemed too sensitive, causing distraction in my cross check
NM-21	1	pilot performance	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Lack of motion and FD's off at no notice was surprising and created some difficulty. Also I use the flight path vector in the airplane for 3o glidepath assistance.
NM-21	2	acceptability		Need the motion on.
NM-21	2	gaining proficiency	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Lack of motion reduced my learning curve
NM-21	2	mental workload; other cues	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Lack of motion required more focus
NM-21	3	control sensitivity	yaw control; pitch control	With motion on, really noticed rudder inputs

PF	Questionnaire	Question	Subquestion	Comment
NM-21	3	handling qualities	pitch control; yaw control; altitude control; overall handling qualities	Yaw seemed too touchy. Pitching down I didn't have the same sensation of less than 1g like in the airplane
NM-21	4	gaining proficiency		No real difference with motion on.
NM-21	4	handling qualities and control strategies		Hard to remain spatially oriented in the morning with the motion turned off
NM-21	4	physical comfort		Same when the motion is on.

APPENDIX 12. COMMENTS ON MOTION BY MOTION GROUP

PF	Questionnaire	Question	Subquestion	Comment
M-01	1	control strategy and technique	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	You can fly the aircraft easier because you can feel the aircraft a lot better than the simulator.
M-01	2	mental workload		Since there seems to be less cues as to what the simulator is doing, the work load is much greater especially when you get off your a/s [airspeed] G/s & loc course.
M-01	2	other cues	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	easier to feel what the aircraft is doing vs simulator
M-01	3	control sensitivity	roll control; pitch control	I tend to overcontrol the pitch & roll due to the lack of my awareness in what amt of input is needed & not having the same feel in the simulator as in the aircraft.
M-01	3	other cues	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	There seems to be more clues as to what is occurring in the aircraft vs. the simulator
M-01	3	pilot performance	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	I feel there are more clues in the aircraft into what is occurring. This fact helps reduce the work load as you don't get so far off your a/s [airspeed], alt, G/s, & LOC.
M-02	1	mental workload		Sim practice always add slightly higher mental workloads almost just because. Mainly because the pilot knows that all the normal cues in the flying environment will not be there.
M-02	1	pilot performance	engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Simulators always have a different feel and cues to the aircrew cannot always be provided. The aircraft provides all those needed cues like sounds or actual motion.
M-02	2	gaining proficiency	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Sim seat-of-the pants cues were felt as more time in the sim was gained.

PF	Questionnaire	Question	Subquestion	Comment
M-02	2	handling qualities	pitch control; bank angle control; yaw control	Mainly because the sim feel causes or can cause over controling [sic] more than the aircraft. For example, simulator feels like "weak lateral stability" rather than "strong lateral stability".
M-02	2	other cues	engine-out straight-in approach/landing	Shifting winds: I would have felt much sooner the dynamics of constant shifting winds.
M-02	2	other cues	engine-out sidestep landing	Microburst: I would have felt much faster the effect of microburst in throttle positions and quick attitude changes.
M-03	1	acceptability		The pitch variation on initiating turns caused some confusion for me.
M-03	1	handling qualities	pitch control; overall handling qualities	Pitch seems a little erratic in turns, felt a pitch up and down when initiating a turn. Altitude- felt it a little harder to maintain altitude in the sim. Pitch caused more airspeed change than I expected. Overall - I think the sim is more sensitive than the airplane in pitch.
M-03	1	other cues	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	NOTE: The sim always feels different for me than the airplane in roll during a visual maneuver. It seems more sensitive
M-03	1	pilot performance	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Straight in approach was off localizer farther with rudder trim out of position than I could feel in the airplane Eng out side step was again off localizer - didn't have rudder trim set for the correction needed.
M-03	2	other cues	engine-out sidestep landing	I have more visual & feel cues in the airplane
M-03	3	mental workload		Trying to adjust for different winds that I would be more alert to in the airplane.
M-03	3	pilot performance	engine-out straight-in approach/landing; engine-out sidestep landing	Felt more visual clues in the airplane would help on flying the approach. Feel acceleration and turn forces better in the airplane.
M-03	4	acceptability		Felt it is more sensitive once it goes into roll it almost feels like its hitting wind shear because the pitch changes so much.
M-03	4	any other aspect		Enjoyed the practice on approaches. Thought the engine out feeling was very close to the airplane reaction would be. Thought tracking localizer more difficult and hard to control.

PF	Questionnaire	Question	Subquestion	Comment
M-04	4	control feel, control sensitivity, and any other cues		The final sim period, the feel, sensitivity felt worse than the earlier periods and worse than the airplane - significantly worse, expecially [sic] with regards to the pitch & aileron and throttle. Also, the control loading on the rudders [sic] seem too heavy.
M-04	4	physical comfort		The last period seemed about the same and perhap [sic] a bit worse than the previous [company] sim - However, the earlier periods in the NASA sim were much more comfortable with regard to nausia [sic], vertigo, motion, etc.
M-06	3	physical comfort		Seems to be a slightly more stable platform despite control inputs.
M-07	1	acceptability		Fidelity/motion seemed a little "sloppier" or looser, yet speed/heading slightly easier to hold
M-07	1	other cues	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	?No inflight experience with eng. failure- I imagine it would be slightly different in terms of feel and noise(?)
M-07	1	pilot performance	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	No experience, but feel I may have done slightly better due to "seat of the pants" feel.
M-07	2	physical comfort		My roll and yaw induced motion seemed to give me more motion sickness than my last simulator.
M-07	2	physical workload		More crosschecking is required due to the lack of airplane "feel" and noise
M-07	3	other cues	engine cut at V1; engine cut at VR	I imagine different yaw & noise cues for both
M-07	4	control feel, control sensitivity, and any other cues		Perceived stability degradation in second half seemed to heighten workload to just fly the simulator. Not many brain cells left for working the engine problem etc. After t/o and climbout, the sim seemed to "bump" as if in mild turbulence and then seemed to start "wandering" becoming sloppy and harder to control.
M-09	1	mental workload		Lack of outside references and seat-of-pants inputs require more crosscheck.
M-09	2	mental workload		Due to lack of outside cues (both physical and visual) crosscheck must be faster in sim than airplane.

PF	Questionnaire	Question	Subquestion	Comment
M-09	3	other cues	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	I have never flown airplane with engine out and never sidestepped. Yaw can not be felt in sim, wind noise is different. There is a lag between control input and sim response.
M-09	3	physical workload; mental workload		Sim lacks some cues and movement that airplane has.
M-10	1	other cues	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Most all clues good, but can't replace actual [vibrations (illegible, pilot clarified to experimenter)] / sound.
M-10	2	acceptability		Very minor comment, a "thud" or two emanating from the sim mechanics could be heard on an occasion or two.
M-10	2	other cues	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Sims do a pretty good job, but the sounds and vibrations are slightly diferent [sic].
M-10	3	other cues	engine cut at V1; engine cut at VR	Cues are not exactltly [sic] same - - Good cues just different
M-10	3	other cues	engine-out straight-in approach/landing; engine-out sidestep landing	Seemed like the acft was on the tip of a rod & seemed to "bobble" on occasion.
M-10	4	control feel, control sensitivity, and any other cues		The aircraft is more stable than the sim, but I think one learns more from an unstable platform. The visual on this sim is one of the best I've seen. - Good feel for flair [sic] alt & rate of decent [sic]. The airplane speed and heading control is better. One can usually look away for a second or two without losing control (no, it really wasn't that bad!) For a light aircraft, the engines didn't seem to respond as in the real acft/ [sic].
M-12	4	any other aspect		My one missed approach felt like I was encountering a strong wind shear, which resulted in great increases in both airspeed and altitude
M-12	4	control feel, control sensitivity, and any other cues		To me a simulator never feels exactly like the airplane. That means that to a great extent flying a simulator well means very quickly [determining] what the differences are. From that point on the problem is how to make the sim do what you want it to do.

PF	Questionnaire	Question	Subquestion	Comment
M-12	4	handling qualities and control strategies		Simulator ques [sic] (signals) are different from the airplane and require a different type of responses [sic] than the airplane. There never seems to be enough of the right kind of sensory feed back to make it feel like the airplane. Feed back always seems to be either too great or too small or non-exsistant [sic].
M-15	1	other cues	engine-out straight-in approach/landing; engine-out sidestep landing	Ground visuals & lack of feel both laterally & horizontally make visual flying very difficult
M-15	2	other cues	engine-out straight-in approach/landing; engine-out sidestep landing	No feel for sink rate or lateral movement
M-15	3	pilot performance	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Sensitivity and lack of feedback in "seat of the pants" feel makes flying the sim much harder than the real airplane
M-15	4	acceptability		A little more difficult to fly than the [company] sim do [sic] to increased sensitivity + waketurb + "burble" incorrect feel + design
M-15	4	control feel, control sensitivity, and any other cues		Simulator vs the airplane - Controls are way too sensitive. The false feeling burbles on the turns were not realistic- windshear example was not realistic with airplane experience- having no fly by the seat of your pants feel adds to difficulty in flying visuals - also yaw control loading seemed way over sensitive when moving rudders [sic] quickly
M-16	2	control sensitivity	yaw control; roll control; pitch control	Like most sims-feel doesn't seem real
M-16	3	control strategy and technique	engine-out straight-in approach/landing; engine-out sidestep landing	More sensitive to wind
M-17	1	acceptability		Very different feel & the 3 axes seemed different from each other. Requires a new learning curve.
M-17	2	mental workload		Simulators seem to require more mental effort than aircraft - kinesthetic feel differences?
M-17	3	control sensitivity; handling qualities	pitch control; yaw control; airspeed control	Sim sentivity [sic] w/o kinesthetics

PF	Questionnaire	Question	Subquestion	Comment
M-17	3	pilot performance	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing	Scan needs & sim feel without kinesthics [sic] of a/c.
M-18	2	other cues	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	as previously stated on the previous survey [The noise level in sim are [sic] usually more pronounce [sic] and no [sic] that realistic. The 747-400 is a noisy airplane. It seems that the noise and feeling on all sim [sic] (767, A-320 etc) are not different from the 747. I think that should be something to compensate according to specific aircraft.]
M-19	1	control feel	rudder input; aileron input; elevator input; yaw trim input; overall control feel	The sim is a little more "mushy" than a/c - ie. The difference in time that you put the input in and you see or feel a response.
M-20	1	handling qualities	altitude control	There is less somatic feel (visual & seat of pants) for small deviations in the sim, than there is in the acft.
M-20	1	mental workload		As I stated earlier, there are less "cues" in the sim. [Therefore,] the crosscheck scan needs to be faster in the sim. There are less cues in the sim that would alert you to a change in the condition (deviation from steady state) of the aircraft.
M-20	4	physical comfort		Very similar feel except for better visual in the clouds (as previously noted)

APPENDIX 13. COMMENTS ON SIMULATOR ACCEPTABILITY[7]

PF	Questionnaire	Comment
M-02	1	As compared to systems, ie. The autothrottle inoperative
M-03	1	The pitch variation on initiating turns caused some confusion for me.
M-04	1	More accurate in all areas especially (1) transition from instruments to visual, (2) x-wind landings, (3) landing maneuvers (4) visual presentation durning [sic] ldg maneuver.
M-07	1	Fidelity/motion seemed a little "sloppier" or looser, yet speed/heading slightly easier to hold
M-08	1	Overall response, control sensitivity is responsive in some areas. But overall great on downwind final mode.
M-11	1	I felt rudder control was sensitive.
M-13	1	Very similar to the last simulator I have flown.
M-16	1	Visual seems improved.
M-17	1	Very different feel & the 3 axes seemed different from each other. Requires a new learning curve.
M-20	1	I wasn't looking outside too much, but the transition from IFR to VFR seemed less disorienting in this sim. This sim seemed a little "tighter" (less mushy).
NM-01	1	This simulator flies more like the A/C [aircraft] in normal operations than the [company] sims. Some items are different cosmetically than the [company] A/C [aircraft]. Font size on PFD and ND are different
NM-04	1	Feel, response + visuals would be 3-4, but the lack of accurate motion falls in the "1" category.
NM-07	1	Very little or no motion felt.
NM-11	1	Only very slight FD differences.
NM-14	1	My last simulator ride was more closely approximating the feel of the airplane. It felt heavier and more stable.
NM-18	1	Too smooth & I didn't sense much yaw.
NM-19	1	Once I get over overcontrolling I think I would like the slightly more sensitive control feel of this sim.
NM-20	1	same as last sheet [The NASA sim is so close to the [company] sims I have a hard time knowing which one is better.]
NM-21	1	Need that motion. Flight director would be nice
M-03	2	Felt the roll and pitch to be more sensitive than the last simulator.
M-04	2	In just about every category, the NASA simulator out perform, with regard to accuracy, controllability visual, over the simulators used in [company simulator facility].
M-05	2	Sensitivity in both roll and yaw axis is more sensitive than our [company] sim.
M-06	2	Despite typically sensitive ailerons, this sim seems to stabilize a little more smoothly.
M-07	2	Motion sickness due to simulator.
M-10	2	Very minor comment, a "thud" or two emanating from the sim mechanics could be heard on an occasion or two.
M-11	2	Again, I had difficulty wrt rudder. Not sure if it's me or not.
M-13	2	Very much a [company] airplane/ simulator.
M-15	2	Due to overly sensitive controls.
M-19	2	Rudder and heading stability and refresh rate of PFD is slow and ratchets.

[7] Note that pilot NM-09 was excluded from all analyses because it was discovered only after his participation that he was not currently qualified on the B747-400 airplane. He was replaced by NM-21.

PF	Questionnaire	Comment
NM-01	2	The motion is less then [sic] the [company] sim. The [company] sim motion is greater at times then [sic] than the A/C. Of course both sim [sic] can not reproduce the feel of some maneuvers. But the [company] sim over compasates [sic] for lack of visual cue's [sic] with too much motion.
NM-04	2	Flying qualities are slightly worse than other sims, but the result would be greater proficiency in the airplane.
NM-05	2	Little ground feel.
NM-07	2	Would have been just like the sim. in [company simulator facility] except for motion and perhaps a more sensitive rudder.
NM-08	2	Pitch sensitivity is higher than in the airplane.
NM-13	2	At [airline company] we have 4 400 sims. Each one is config'd a little different with the visual ranging from good to xlnt [excellent]. This one here is equivalent to our best sim at [company airline]. Make training, flying and proficiency better.
NM-16	2	Only in the lack of motion.
NM-18	2	The ability to evaluate the approach on the (N.D.) is an excellent teaching tool. This should be incorporated in to all sims.
NM-19	2	See previous [Had some disorientation before last sidestep maneuver. Never experienced that before in a sim - may have been lack of sleep night before!]
NM-20	2	Noticed occasional heading jumps that I don't rember [sic] from [company] sim.
NM-21	2	Need the motion on.
M-03	3	Seems to me that the pitch and yaw is more sensitive than other 747-400 simulator.
M-04	3	Still better than last sim flown at [airline company]
M-07	3	Heavier on controls, sloppy, wandering more.
M-10	3	Didn't seem to be as stable as last sim.
M-13	3	Visual system more life-like.
M-17	3	Seems more squirelly [sic], i.e. mobile.
M-19	3	The absence of flight director makes the approach more difficult.
M-20	3	See previous page comments.[I normally don't have much discomfort in the sim. However, I did notice this sim has more visual cues when it comes to flying through clouds (IFR) than the [company] sims. (There is a gray scale in the clouds)]
NM-01	3	The yaw indicator. I think the [company] sim's yaw-skid indicators are less sensitive, thus move less. I am not sure how the aircraft truly reacts in a engine out situation. The [company] sim is easier to fly, but does not mean that it truly simulates the aircraft.
NM-04	3	The yaw sensitivities made it slightly worse.
NM-10	3	Short of feeling funky the simulator was fine.
NM-11	3	Almost too sensitive, too reactive - borderline.
NM-17	3	Better physical comfort.
NM-18	3	Not sure now what is accurate to the acft feel.
NM-19	3	More responsive in some controls and better cues. Seems more stable in roll/pitch

APPENDIX 14. COMMENTS ON PHYSICAL COMFORT[8]

PF	Questionnaire	Comment
M-02	1	With the exception of pitch trim of the NASA-400 sim.
M-04	1	Visual syst much more accurate & realistic
M-06	1	I do not tend to experience sim induced disorientation, but being "busy" while in the sim also seems to reduce those effects. Most occurances [sic] happen, (for me) while taxiing.
M-07	1	Possibly from my own pilot-induced oscillations, but felt a bit queasy for a few seconds during rudder/aileron inputs/rolls.
M-17	1	Lots of forces acting on body
NM-01	1	I do not have problems with simulator-induced disorientation but the sim motion was not rough enough. It is hard to say if this perception is from other sims or the airplane. Because the engine out work is in the sim.
NM-04	1	Not better or worse, but the motion fidelity is not at all like other sims. Motion cues seemed non-existant [sic] throughout this session. Visual picture on landing roll seemed to appear "lower" to ground than normal.
NM-12	1	Just a little unfamiliar. No nausea.
NM-17	1	Less pitch and roll swing effect seemed to offer less disorientation.
NM-19	1	Visual seemed better - Pictures seemed to be update[d] more frequently -seemed more real time and not a[s] bright a picture as [company] sim (more realistic).
NM-20	1	The NASA sim is so close to the [company] sims I have a hard time knowing which one is better.
NM-21	1	My head was almost tumbling on final.
M-04	2	Correlation between sim & visual much more accurate during visual segments, especially during transition from IMC to VMC, and during landings.
M-06	2	No observed symptoms in this sim. Usually only have experienced any symptom while taxiing a simulator.
M-07	2	My roll and yaw induced motion seemed to give me more motion sickness than my last simulator.
M-11	2	First time I took note. Visual was great.
M-13	2	Better visual - more life like especially in the clouds.
NM-01	2	I can not be certian [sic] the motion was on.
NM-04	2	Lack of accurate motion ques [sic] had no effect on my comfort.
NM-10	2	At [airline company] when on the ground and taxiing around [in the sim], there is a slightly disorienting feeling. It seems the [company] sim may be more sensitive and therefore less real in that operating environment.
NM-14	2	Maybe cool the simulator a little more. Its rather stuffy.
NM-16	2	I don’t tend to suffer from these symptoms.
NM-17	2	During maneuvering the visual orientation is less disorienting much better graphical representation.
NM-18	2	The visual during set up was annoying. [pilot drew a circle surrounded by wavy lines]
NM-19	2	Had some disorientation before last sidestep maneuver. Never experienced that before in a sim - may have been lack of sleep night before!
NM-21	2	Discomfort was not too bad until I went visual on the sidestep, and then I had to focus more on gauges and attitude on the PFD for clues.
M-01	3	Pretty much the same except in the simulator I knew if I crashed the consequences of that was not dying.
M-04	3	Still better than that last flown at [airline company].
M-06	3	Seems to be a slightly more stable platform despite control inputs.

[8] Note that pilot NM-09 was excluded from all analyses because it was discovered only after his participation that he was not currently qualified on the B747-400 airplane. He was replaced by NM-21.

PF	Questionnaire	Comment
M-08	3	Need better lighting in upper EICAS! Could not interpret engine parameters.
M-10	3	NASA simulator seemed to "bobble" and "roll" more and graphics outside cockpit reflected that.
M-11	3	The only exception is when making rapid/large pitch correction. I felt a little spacial disorientation wrt visual.
M-20	3	I normally don't have much discomfort in the sim. However, I did notice this sim has more visual cues when it comes to flying through clouds (IFR) than the [company] sims. (There is a gray scale in the clouds)
NM-01	3	I never have experienced nausea of simulator-induced disorientation.
NM-04	3	Excessive yaw sensitivities create excessive motions. It appears motions in all axes reflect what sim is doing however.
NM-10	3	I felt wierd [sic]. Really focused on the instruments to get away from the sensations. My head was swirling the entire time. Real effort was expended to concentrate on the instruments. At times the instrumentation did not seem correct. However, I continued to fly the instruments.
NM-11	3	Good headrests.
NM-14	3	Need more temperature control.
NM-17	3	Less sim-induced disorientation.
NM-18	3	Yaw seems exaggerated at times…?
NM-20	3	Had one case of disorientation on final that was not present before break.

APPENDIX 15. COMMENTS ON WORKLOAD[9]

PF	Questionnaire	Type of Workload	Comment
M-01	1	mental workload	Because it is easier to fly the aircraft, it is mentally a lot harder to fly the simulator as you get off your airspeed, altitude, glidepath, centerline etc a lot more.
M-02	1	mental workload	Sim practice always add slightly higher mental workloads almost just because. Mainly because the pilot knows that all the normal cues in the flying environment will not be there.
M-02	1	physical workload	The same, because crews (same company) know their SOP's and can anticipate the sequence
M-03	1	mental workload	Used to having VNAV programmed for engine out profile.
M-04	1	physical workload; mental workload	Extremely proficient F/O w/ specific manevers [sic]
M-06	1	physical workload; mental workload	Simulator flying is perceived to be more demanding and usually "not as real" as the plane. Its easier to get focused on a particular task and let checklists/flying slip by or stagnate.
M-07	1	mental workload	In sim, less to worry/plan for the landing, passengers, flight attendants, company etc.
M-09	1	mental workload	Lack of outside references and seat-of-pants inputs require more crosscheck.
M-09	1	physical workload	Simulator controls are slightly harder and less responsive than airplane.
M-10	1	physical workload	Only slightly higher due to the fact that we train to use the autopilot more (as a mater of fact, we never practice useing [sic] throttles on take off (autothrottle) and we turn on the a/p at 500'
M-10	1	mental workload	Slightly higher due to not useing [sic] same aircraft config (and we almost always use flight director. - always in simulator)
M-11	1	mental workload	I felt that I devoted a lot of brain power to rudder control. Also, being used to using the glass, reverting to raw data increases mental workload a lot.
M-12	1	mental workload	Only have to think about the airplane (No WX, PAX, F/A problems)
M-13	1	physical workload	Non [airline company] SOP's added a little work.
M-14	1	mental workload	Difference in procedures (Those not required). Adjustments to mindset for deletion of operating equip mental lag from just completed trip (16+ hour time change)
M-15	1	physical workload; mental workload	Again-rudder control made workload higher.
M-16	1	physical workload	Some checklists are eliminated.
M-17	1	mental workload	The [feel changes that are not the same in all 3 axes] cause a lot of mental adjustment.
M-17	1	physical workload	Feel changes require learning a "new machine" and are not the same in all 3 axes.
M-18	1	physical workload	see previous comments [In these sim you tend to overcompensate more than the airplane because sim is more light sensation. Airplane feels heavier. (This answer apply to other questions too).]

[9] Note that pilot NM-09 was excluded from all analyses because it was discovered only after his participation that he was not currently qualified on the B747-400 airplane. He was replaced by NM-21.

PF	Questionnaire	Type of Workload	Comment
M-20	1	mental workload	As I stated earlier, there are less "cues" in the sim. [Therefore,] the crosscheck scan needs to be faster in the sim. There are less cues in the sim that would alert you to a change in the condition (deviation from steady state) of the aircraft.
NM-01	1	mental workload	Because I did not have to worry about: checklist, passengers, company, OPS, SAM (maintenance), FAR'S and real life consequences for my actions
NM-02	1	mental workload	Different attitude in airplane vs. simulator. Wont actually die in the simulator - - just get embarrassed. In the aircraft, I would be fighting for my/our lives
NM-03	1	mental workload	Rushed.
NM-03	1	physical workload	Due to differences in control feel, sensitivity etc that were noted prior.
NM-04	1	physical workload; mental workload	Multiple No-notice degrades on top of briefed degrades and PNF using "different" SOPs were tough.
NM-04	1	mental workload	Several times I had to make "assumptions" real-time, based on my understanding of the study goals.
NM-07	1	mental workload	Had to rely much more on instruments because of lack of motion in sim.
NM-08	1	mental workload	Rarely have flown raw data ILS in airplane.
NM-10	1	mental workload	Slightly higher to moderately higher. Did not expect the unexpected so soon. So my "cup" got full very quickly.
NM-11	1	mental workload	No real danger of crashing, fortunately tough to simulate.
NM-11	1	physical workload	The flight director off significantly increases the workload, especially engine out.
NM-12	1	mental workload	Unfamiliar setting, slightly different set up.
NM-13	1	mental workload	With all disc[ontinuities] + failures "corrected" immed, no more mental workload other than flying a/c is req'd.
NM-14	1	mental workload	Being less stable, I couldn't relax. I was always adjusting the trim to maintain HDG, alt. Constant control inputs were necessary.
NM-14	1	physical workload	Because the sim was so light it didn't take much effort to make the plane respond.
NM-15	1	mental workload	Some displays / FMC functions are dissimilar to company a/c.
NM-16	1	mental workload	When the flight path deviates from my target (speed, attitude etc.), I had to rely purely on my scan to detect it. There is little other input that you normally get in the a/c. I.E. changes in sound, sense of motion, etc.
NM-17	1	physical workload	[slightly higher] Especially in yaw imput [sic]. The sim requires more input because of lack of subtle seat of the pants cues. If those cues were present much finer and more frequent adjustments can be made.
NM-18	1	mental workload	F/D off was more [underlined] of a mental load. However, overall with F/D off in aircraft it was not as great a load due to less distractions… radios, passengers, flt att...etc.
NM-19	1	physical workload	Other than pitch the physical (overall) workload seemed better because the sim flew more like a lighter A/C.
NM-20	1	mental workload	The mental is less because their [sic] is less outside input as opposed to A/C. No F/A, dispatch etc.

PF	Questionnaire	Type of Workload	Comment
NM-20	1	physical workload	Keeping the yaw solved is harder in the sim which keeps the physical work load higher.
NM-21	1	physical workload	Lack of flight directors, FPV's and motion made it more difficult. Also, slip indicator seemed too sensitive, causing distraction in my cross check
M-01	2	mental workload	Since there seems to be less cues as to what the simulator is doing, the work load is much greater especially when you get off your a/s [airspeed] G/s & loc course.
M-02	2	physical workload	Its higher because without watching aerodynamic cues sooner caused the workload to increase.
M-04	2	physical workload; mental workload	Again, experienced F/O who is familiar with routine, but in airplane we would probably "unload" by using F/D and autopilot more during approaches and VNAV during T/O.
M-06	2	physical workload	Simulator workloads generally seem, at least to me, to be a little higher than in the plane because more things are happening w/ regards to manuver [sic] accomplishment, briefings and procedural items.
M-07	2	mental workload	Although more crosschecks, less mental preparation for briefing F/A's, PAX etc.
M-07	2	physical workload	More crosschecking is required due to the lack of airplane "feel" and noise
M-09	2	mental workload	Due to lack of outside cues (both physical and visual) crosscheck must be faster in sim than airplane.
M-09	2	physical workload	Had to speed up crosscheck due to slightly different control responses in sim versus airplane.
M-10	2	mental workload	Once again, I feel a little more "at home" in the normal tng environment but, this is not terribly different.
M-10	2	physical workload	Slightly higher initially, only because of the non-std configuration, to slightly lower on 2nd & 3rd attempt.
M-11	2	mental workload	Again, raw data approach adds to workload.
M-11	2	physical workload	Raw data is a lot more work.
M-12	2	mental workload	Flying the simulator is easier because there are no (fewer) external problems.
M-13	2	mental workload	As above, a lot of mental workload on flying.
M-13	2	physical workload	Seems to be not as stable i.e. I'm spending a lot of "mental time" flying.
M-14	2	mental workload	Due to jet lag and fatigue.
M-14	2	physical workload	Mainly due to compensating for control differences. Not significantly different.
M-15	2	physical workload; mental workload	Have to compensate for overly sensitive controls.
M-16	2	mental workload	Higher because of type of event.
M-17	2	mental workload	Simulators seem to require more mental effort than aircraft - kinesthetic feel differences?
M-18	2	physical workload	[all sic] For reasons stated before. Because you have to adjust for the sensitiveness of the sim. So you workload increases. Sometimes because of this, if a person is a little off in the sim and let this affect him because of the sim being not as stable as airplane their scan suffers. Making him overcompensate more.
M-19	2	mental workload	Had to keep cross-check going faster and concentrate more because rudder and bank didn't hold desired outcomes.

PF	Questionnaire	Type of Workload	Comment
M-19	2	physical workload	Once I made an input to rudder and/ or heading and it seemed to work, I had to change it.
NM-01	2	mental workload	Less visual cue's [sic] and less motion.
NM-03	2	physical workload; mental workload	Same as prior mostly due to sensitivity issues with controls. (This is OK).
NM-04	2	physical workload; mental workload	Increased workload due to degrades , increased monitoring of basic control parameters. Trimming yaw is useless.
NM-07	2	mental workload	Have to rely more on instruments because of lack of motion/ A/C feel.
NM-08	2	mental workload	Pitch sensitivity caused glide slope mental workload to be higher.
NM-08	2	physical workload	Pitch sensitivity caused higher workload.
NM-10	2	mental workload	W/o FD or autothrottles increased scan and a different scan is required. Mentally more challenging in that aspect.
NM-11	2	mental workload	Still lower stress than it would ever be in the aircraft.
NM-11	2	physical workload	Engine out, no autothrottle, no flight director, sidestep, this is multiple problems hopefully seen only it simulator environment (but great training)!
NM-12	2	mental workload	A little stress of adaptation.
NM-13	2	mental workload	You know what is going to happen, no checklists or manuals to read. Just fly the plane.
NM-14	2	physical workload	It seems that you have to be more vigilant to maintain hdg and glide slope. Once you get off your desired hdg you have to take care not to over correct. Roll rate seems quicker.
NM-16	2	mental workload	You have to constantly focus on your instruments to maintain desired attitude. The simulator feels less stable and ther [sic] is less other feedback to detect changes in attitude/ airspeed.
NM-18	2	mental workload	F/D of ILS requires much more attention than with the A/P and F/D (ie normal ops). Other distraction were not observed (i.e. radio, traffic etc.).
NM-18	2	physical workload	Only because we normally use F/D and A/P more frequently on aircraft.
NM-19	2	mental workload	Just a result of better cues (see previous) and less physical demands.
NM-19	2	physical workload	Somewhat lighter control forces and slightly increased sensitivity - not a lot but seems noticeable.
NM-20	2	mental workload	Less other distractions - F/A's, dispatch, ATC etc.
NM-20	2	physical workload	More attention to yaw/HDG
NM-21	2	mental workload	Lack of motion required more focus
M-01	3	mental workload	Because the aircraft is easier to fly, the mental concentration is much higher in the simulator than the aircraft.
M-03	3	mental workload	Trying to adjust for different winds that I would be more alert to in the airplane.
M-03	3	physical workload	Lots of adjustment to rudder required more so than in the airplane with engine out.
M-04	3	physical workload; mental workload	Again, seemed to require more attention.
M-06	3	physical workload; mental workload	Sims seem to increase work load - more stuff happening more quickly
M-07	3	mental workload	Now I have to scan more diligently, raising my mental effort to try to compensate.

PF	Questionnaire	Type of Workload	Comment
M-07	3	physical workload	Heavy, sloppy controls.
M-09	3	physical workload; mental workload	Sim lacks some cues and movement that airplane has.
M-10	3	physical workload; mental workload	Sim seemed more unstable [sic], requiring more input & faster cross-scan.
M-11	3	mental workload	Again raw data flying and struggling with rudder makes more mental work.
M-12	3	mental workload	No external problems added.
M-13	3	mental workload	As mentioned before I mentally felt behind things.
M-14	3	mental workload	As mentioned on page 7 [Definite impact of fatigue from jetlag (trans pacific crossing day prior) affecting problem recognition/solution time interval]
M-15	3	physical workload; mental workload	Same as before.
M-16	3	mental workload	Concerned now about LOC alignment.
M-17	3	mental workload	More physical work means more mental work.
M-17	3	physical workload	Difficulty in keeping up means there are corrections which require more work.
M-18	3	physical workload; mental workload	Same reason stated page 7. [After the break and because the lunch my performance I felt I little worse. My concentration and scanning were different. Needed more time to concentrate.]
M-20	3	mental workload	Must rely more heavily on crosscheck to detect deviations from steady state.
NM-01	3	mental workload	Because of the nature of the sim environment, "Dark" low light no depth perception when looking at item on a CRT (out the window). The sim also flies a little different thus one has to be more attentive to hand flying.
NM-03	3	physical workload	Same as prior - Sensitivity and stability cause more physical [workload].
NM-03	3	mental workload	Same for mental effort. (As previously stated this is ok because it makes it easier to fly aircraft)
NM-04	3	physical workload	Same as before; briefed and unbriefed system degrades and increased yaw sensitivities increased workload.
NM-10	3	mental workload	Since I feel funky it seemed like I was focusing very hard on the instrumentation to get away from that funky feeling.
NM-10	3	physical workload	I felt like I was working harder than before. Or than when I work in the A/C.
NM-11	3	mental workload	Still a sim.
NM-11	3	physical workload	I seemed to overcontrol, a little P.I.O (pilot induced) (pitch and roll).
NM-16	3	mental workload	Higher concentration required due to less cues as to changing airspeed or attitude. Also sim seems less stable.
NM-17	3	mental workload	Interpretation of instrument info during Vr cut/windshear scenario was hampered by reduced physical cues.
NM-18	3	mental workload	Non F/D approaches are always challenging.
NM-18	3	physical workload	More concentration required. Cant [sic] depend on senses!
NM-19	3	mental workload	Both about the same - maybe a little easier mentally/ physically in sim due to improved cues. (I'm beat - hard to tell)
NM-20	3	mental workload	Again fewer outside distractions F/A / ATC / dispatch
NM-20	3	physical workload	More crossceck for rudder and heading than in a/c.

APPENDIX 16. COMMENTS ON CONTROL FEEL[10]

PF	Questionnaire	Control Input	Comment
M-02	1	rudder input; aileron input; elevator input; yaw trim input; roll trim input; pitch trim input; overall control feel	Simulator vs aircraft overall was heavier
M-03	1	rudder input; aileron input; elevator input; overall control feel	Aileron feels more lighter in turns - elevator feels lighter with speed changes - rudder feels heavier with engine out of control - Overall controls felt a little lighter than airplane
M-06	1	aileron input; roll trim input; overall control feel	Did not use Aileron/Roll trim. Overall very close to airplane w/ exception of ailerons- but most 400 simulators seem more sensitive in roll.
M-07	1	rudder input	I have never made large rudder inputs in the airplane thus it is difficult to judge the difference (No eng failures in real airplane).
M-08	1	rudder input; aileron input; elevator input; throttles; yaw trim input; roll trim input; pitch trim input; overall control feel	Slow to respond.
M-09	1	roll trim input	Did not use roll trim.
M-09	1	rudder input; aileron input; elevator input; yaw trim input; pitch trim input; overall control feel	Elevator input is stiffer and less responsive and has a time lag between input and pitch movement.
M-10	1	elevator input; overall control feel	Elevator on takeoff feels slightly lighter to aircraft, but could be due to trim setting.- - Otherwise it feels close (in reality, it may also be due to max thrust take-off on a light acft) Overall control was very close, but it did seem on some occasions to be slightly lighter.
M-11	1	roll trim input	Did not use roll trim.
M-12	1	rudder input; aileron input	Rudder felt much too sensitive.
M-13	1	rudder input; aileron input; throttles; overall control feel	Seems as though less trim (rudder especially) was required in this simulator to get desired response from my past experiences.

[10] Note that pilot NM-09 was excluded from all analyses because it was discovered only after his participation that he was not currently qualified on the B747-400 airplane. He was replaced by NM-21.

PF	Questionnaire	Control Input	Comment
M-14	1	rudder input; aileron input; elevator input; throttles; pitch trim input; overall control feel	Control loading feels as though pressure forces slightly less than required in normal aircraft.
M-16	1	rudder input; aileron input; elevator input; yaw trim input; roll trim input; pitch trim input; overall control feel	Control inputs are lighter and respond quicker than aircraft.
M-17	1	rudder input; elevator input; yaw trim input; pitch trim input	Yaw very light and sensitive. Pitch heavy and ponderous. Roll about normal.
M-18	1	rudder input; aileron input; elevator input; throttles; yaw trim input; roll trim input; pitch trim input; overall control feel	In these sim you tend to overcompasate [sic] more than the airplane because sim is more light sensation. Airplane feels heavier. (This answer apply [sic] to other questions too).
M-19	1	rudder input; aileron input; elevator input; yaw trim input; overall control feel	The sim is a little more "mushy" than a/c - ie. The difference in time that you put the input in and you see or feel a response.
NM-01	1	throttles; yaw trim input; roll trim input	Throttles, yaw trim input, and roll trim input not normal [sic] used or used enough to make judgment
NM-02	1	roll trim input	Never used Roll Trim input in airplane or simulation
NM-03	1	rudder input; aileron input; elevator input; throttles; yaw trim input; roll trim input; pitch trim input; overall control feel	Overall control loading moderately lighter especially in very beginning of motion.
NM-04	1	rudder input; aileron input; elevator input; pitch trim input; overall control feel	Appears to be a "slightly" lighter feel compared to airplane, but this is almost negligible, and not significant in my view.
NM-08	1	rudder input; pitch trim input; overall control feel	Rudder feels just a little lighter than airplane. Pitch is more sensitive, slightly heavier.

PF	Questionnaire	Control Input	Comment
NM-10	1	rudder input; yaw trim input	Rudder input and yaw trim input-based on experience (engine out in simulators) was 3/4 of what I expected. Rudder was at 3 on engine out final, I expected 4 units. It seemed sensitive too.
NM-10	1	elevator input	Elevator input - noticed lighter than what I expected. This could be based on low gross weight (550,000). I typically fly heavy gross weights (800,000).
NM-10	1	overall control feel	Overall control feel - seemed sensitive. Pitch and yaw primarily seemed lighter. It also seemed light. The motion was off. Not much seat of the pants especially on landing.
NM-12	1	rudder input; aileron input; elevator input; throttles; pitch trim input; overall control feel	The control feel seemed more responsive than the aircraft. The aircraft seems to be more pronounced in its control feel, a more positive feedback of control forces.
NM-14	1	aileron input; elevator input; throttles; overall control feel	The trim happened faster than I am used to. Overall the sim seemed more responsive than the aircraft.
NM-15	1	pitch trim input	Pitch Trim: Control feel a bit "unstable".
NM-16	1	rudder input; aileron input; elevator input; pitch trim input; overall control feel	Pitch control seemed heavier while roll and yaw felt heavier. However, yaw inputs tend to be minimal when flying the line.
NM-17	1	rudder input; aileron input; yaw trim input; pitch trim input; overall control feel	Controls in the sim seem mushier than the aircraft. Imputs [sic] incur a minute delay which has the tendency to want to make you add further input thus over controlling, even if slightly. The [This] forces more correction control movements than is required in the aircraft.
NM-18	1	rudder input; yaw trim input; overall control feel	The rudder and yaw inputs seemed lighter than the acft.
NM-19	1	rudder input; aileron input; elevator input; throttles; yaw trim input; pitch trim input; overall control feel	Control feel generally seems pretty accurate. I'm fairly ham fisted initially so I may have different opinion later.
NM-21	1	rudder input; aileron input; elevator input; pitch trim input; overall control feel	Feels lighter, possibly due to motion off, or lighter gross weight than I normally use in the sim
M-01	2	elevator input	Slightly lighter
M-02	2	rudder input	Simulator pressure inputs required a little more effort to find the correct input.
M-03	2	elevator input	Pitch Control seems lighter
M-04	2	elevator input	Responds to movement and not as receptive to pressure inputs.

PF	Questionnaire	Control Input	Comment
M-05	2	rudder input; aileron input	More sensitive
M-05	2	yaw trim input	A degree different from what I'm used to.
M-06	2	aileron input	Lighter
M-06	2	elevator input	Just slightly heavier
M-08	2	rudder input	Rudder input was not as responsive.
M-09	2	roll trim input	Did not use roll trim input
M-11	2	rudder input	I seem to have trouble "keeping ball centered." Devoting a lot of time on rudder. Seems sensitive to me.
M-12	2	rudder input	Rudder in airplane requires more effort
M-16	2	rudder input	More sensitive could be the wind.
M-17	2	rudder input; aileron input	Seem slightly lighter than airplane
M-19	2	aileron input	To [sic] light
M-19	2	elevator input	Doesn't have hesitation on takeoff around 10.5 deg pitch - may be due to light weight t/o@ 550. Control loading about same otherwise.
NM-04	2	rudder input; aileron input; elevator input	all yoke inputs seemed a little lighter. Throttles seemed ok
NM-05	2	rudder input	Much to [sic] light
NM-05	2	aileron input	Light
NM-05	2	elevator input; throttles; yaw trim input; pitch trim input	Same
NM-06	2	rudder input; aileron input	Lighter
NM-07	2	rudder input	More sensitive than [company] sim and a/c [aircraft].
NM-15	2	rudder input; aileron input; elevator input; throttles; yaw trim input; pitch trim input	(A/C) sim felt a bit "unstable" in all axes. This instability may be attributed (corellated [sic]) to control feel.
NM-16	2	rudder input; elevator input	Both seemed to require less force than the a/c to affect a change.
NM-18	2	rudder input	<u>Too soft not abrupt enough</u>
NM-18	2	aileron input	<u>Too soft should be more abrupt with flaps > 25</u>
NM-18	2	yaw trim input	Seems like more trim should be indicated 2-3 unts [units]
NM-18	2	rudder input; aileron input; elevator input; throttles; yaw trim input; roll trim input; pitch trim input	Seems like motion is off many times.
NM-20	2	rudder input	Mainly rudder.
M-03	3	aileron input; elevator input; overall control feel	Overall still feels sensitive than airplane in roll and pitch.

PF	Questionnaire	Control Input	Comment
M-07	3	aileron input; elevator input; overall control feel	Did not use Roll trim.
M-08	3	rudder input	Full rudder for a S/E failure?
M-18	3	rudder input; aileron input; elevator input; throttles; yaw trim input; roll trim input; pitch trim input; overall control feel	Same reason as previously stated. [In these sim you tend to overcompasate [sic] more than the airplane because sim is more light sensation. Airplane feels heavier.] Rudder input felt slightly heavier.
NM-02	3	elevator input	Elevator in light turbulence feels too heavy. Feels like I'm fighting trim inputs.
NM-10	3	rudder input; elevator input; throttles; overall control feel	Rudder input - in terms of feel, in this period I had more recognition of rudder "feel." It was slightly heavier than what I would expect in the a/c. Elevator input - was slightly heavier as I noticed on rotation and level off. Throttles - seemed more sensitive than the actual a/c. The power reference points seemed further back and they were sensitive in terms of corrective responses.
NM-15	3	throttles	Throttles: Require constant manipulation to maintain target airspeed.

APPENDIX 17. COMMENTS ON CONTROL SENSITIVITY[11]

PF	Questionnaire	Control	Comment
M-02	1	yaw control; roll control; pitch control; overall control sensitivity	Aircraft is more precise with smaller inputs that do not lead to over control. The sim was very nose heavy and correct pitch trim was hard to find. On level off and establishing level flight at 250 IAS or 210 IAS setting known trim setting for cruise flight were not the same. When doing so, pitch was or took extra workload to stay at constant altitude.
M-03	1	yaw control	Yaw - had to use more effort with rudder than I thought I would in the aircraft with engine out.
M-04	1	yaw control; roll control	Sim appears more stable than a/c. Roll control in sim appears less sensitive during x-wind ldgs [cross wind landings].
M-06	1	roll control	Most sims (400) have difficulty matching aileron roll sensitivity.
M-07	1	yaw control; roll control	Difficult to judge sensitivity due to lack of experience with large control inputs in airplane experience (no eng failures in airplane).
M-08	1	yaw control; roll control; pitch control; overall control sensitivity	Slow to respond
M-09	1	yaw control; roll control; pitch control; overall control sensitivity	Elevator is stiffer and time lag between input and pitch movement.
M-10	1	pitch control	Once again, aircraft seemed to be somewhat light (but not too bad).
M-11	1	yaw control; overall control sensitivity	I spent a lot of focus on rudder. Seems it was pretty sensitive and it lagged. (I was behind wrt. input & response).
M-12	1	yaw control; roll control	Rudder input too sensitive at all times.
M-13	1	roll control; overall control sensitivity	As in previous explanation, simulator seems "touchy" and inputs seem somewhat overcompensated i.e. Airplane seems more stable
M-14	1	yaw control; roll control; pitch control; throttle control; overall control sensitivity	Sensitivity slightly less than operable aircraft.
M-15	1	yaw control; pitch control; overall control sensitivity	Rudder seemed to generate a much larger response with very little rudder input. Difficult to control with slight pressure - Pitch was the same just a bit lighter.
M-16	1	yaw control; roll control; pitch control; overall control sensitivity	Sensitive enough that you have a tendency to over control.

[11] Note that pilot NM-09 was excluded from all analyses because it was discovered only after his participation that he was not currently qualified on the B747-400 airplane. He was replaced by NM-21.

PF	Questionnaire	Control	Comment
M-18	1	yaw control; roll control; pitch control; throttle control; overall control sensitivity	See previous comment [In these sim you tend to overcompasate [sic] more than the airplane because sim is more light sensation. Airplane feels heavier. (This answer apply [sic] to other questions too).]
NM-03	1	yaw control; roll control; pitch control; overall control sensitivity	Overall control sensitivity slightly less sensitive again in initial phase of control movement.
NM-04	1	yaw control; roll control; pitch control; overall control sensitivity	Overall simulator appears to have "lighter" control response may be due to lighter gross weight used in this unit.
NM-05	1	yaw control	Yaw in aircraft (is more responsive)
NM-10	1	yaw control	Yaw control- seemed like slightly more sensitive. The turn/slip indicator moved alot [sic] with small rudder trim inputs.
NM-10	1	pitch control	Pitch control- seemed like slightly more sensitive. Coming off the runway on 2nd take-off. With VR cut the aircraft seemed to jump off the ground with my input which seemed to be at about 2-3 [deg]/sec. Again, may be result of low gross weight.
NM-10	1	overall control sensitivity	Overall control sensitivity- slightly more sensitive than the A/C for above stated reasons.
NM-12	1	yaw control; roll control; pitch control; throttle control; overall control sensitivity	Again, the sim seems to be more sensitive than the aircraft with regards to sensitivity of the controls.
NM-13	1	roll control; pitch control; overall control sensitivity	Sim is lighter in most responses. Aircraft feels heavier and has an initial slow response at initial input to ail + elev.
NM-14	1	yaw control; roll control; pitch control; overall control sensitivity	The yaw control was significantly different than the aircraft. Just a little pressure resulted in large variations in the inclinometer. The airplane "feels" heavier and more stable.
NM-15	1	roll control; pitch control; overall control sensitivity	Roll) requires seemingly less [aileron] input. Pitch) more pitch sensitive (requires trim inputs more often). Overall sensitivity) seems less stable than a/c.
NM-16	1	yaw control; pitch control; overall control sensitivity	Again, because yaw inputs on the line tend to be minor, it is difficult to judge the sensitivity. Based only on instrument feedback, the yaw response seemed quite sensitive for the amount of rudder deflection. The aircraft gives much more physical feedback of yaw motion.
NM-17	1	yaw control; roll control; pitch control; overall control sensitivity	Throttles are just like the aircraft except the sound of spool up. They tend to spool up more radically, otherwise feel is identical. Feel in roll is mushy as is pitch. Yaw appears to require more imput [sic] than the real aircraft.

PF	Questionnaire	Control	Comment
NM-18	1	yaw control; throttle control; overall control sensitivity	Yaw was controllable once accustomed to required input. A/S [airspeed] seemed very stable.
NM-19	1	yaw control; roll control; pitch control; overall control sensitivity	Seems as if control sensitivity is more like that of a heavier a/c. Rotation seems dampened for 500,000 lbs A/C. Yaw sensitivity could just be my initial overcontrolling of rudders [sic].
NM-20	1	yaw control; roll control	Yaw control is more sensitive. The yaw indicator moves quicker with less input from rudder than the airplane.
M-02	2	roll control; pitch control	Simulator caused more overcontrol than actual aircraft.
M-03	2	pitch control	Pitch seems a little more sensitive.
M-04	2	pitch control	again-does not appear to be as sensitive to pressure inputs vrs actual control movement.
M-06	2	roll control	Slightly lighter and quicker to roll inputs.
M-08	2	yaw control	Slightly more sensitive.
M-11	2	yaw control	I am chasing "the ball" a lot.
M-11	2	yaw control; roll control; pitch control; throttle control	Note: in close, controls feels fine. Maybe the rudder perception is just me.
M-12	2	yaw control	Rudder more sensitive than airplane
M-12	2	roll control	Ailerons slightly more sensitive than airplane.
M-13	2	yaw control; roll control; pitch control; throttle control	Overall the actual airplane seems to be more stable than this & most simulators
M-13	2	roll control	Seems to "react" more than the airplane
M-15	2	yaw control; roll control	Much more sensitive
M-16	2	yaw control; roll control; pitch control	Like most sims-feel doesn't seem real
M-20	2	yaw control; roll control; pitch control; throttle control	The only major difference I can detect is in that when flaps are dropped from 10 [to] 20 degrees the simulator "balloons" excessively (pilot must pitch down in order to stay on glidepath). The aircraft has a tendency to balloon when flaps go from 25 to 30 but not nearly to the extent this sim does (aircraft is about 50% less than the sim).
NM-02	2	throttle control	When on speed I properly configured approaching the glide path - the power reduction to attain : keep the glidepath is more than aircraft or [company Boeing] 747-400 sim.
NM-03	2	yaw control; roll control; pitch control	Difference is in initial response or initial portion of control movement.

PF	Questionnaire	Control	Comment
NM-04	2	yaw control	Yaw seemed much more sensitive (trim + rudder inputs) than a/c. Once I severely restricted my yaw inputs my flying improved. This increased yaw sensitivity probably affects my perception of overall "more sensitivity" of the sim.
NM-05	2	yaw control	No feel.
NM-05	2	yaw control; roll control; pitch control; throttle control	Don't feel motion in sim.
NM-06	2	yaw control; roll control; pitch control	Lighter
NM-10	2	roll control	A slower roll response rate is what I remember from the a/c. Kind of a heavier feel.
NM-15	2	yaw control; roll control; pitch control	Seems more sensitive than actual aircraft.
NM-16	2	yaw control; pitch control	Both seemed much more sensitive than the a/c. The a/c tends to feel much more stable and not jump around with control inputs like simulator does.
NM-18	2	yaw control	Again to [sic] soft, hardly feel the rudder input
NM-18	2	roll control	Again to [sic] soft, hardly feel the rudder input Should be more abrupt movement of ailerons with flaps >25
M-01	3	roll control; pitch control	I tend to overcontrol the pitch & roll due to the lack of my awareness in what amt of input is needed & not having the same feel in the simulator as in the aircraft.
M-02	3	throttle control	Throttle control: Deceleration takes longer than airplane, with a decrease in power.
M-03	3	yaw control; pitch control	Roll more sensitive in starting turn, seems erratic at the initiation of turns. Pitch seems more sensitive than airplane.
M-04	3	roll control; pitch control; overall control sensitivity	Just seems more sensitive?!
M-06	3	yaw control; roll control; pitch control; overall control sensitivity	Rudder & aileron seemed more sensitive Pitch trim seemed slower and a little heavier.
M-07	3	roll control; pitch control; overall control sensitivity	Seemed very heavy in pitch, wandered more in pitch, my hand felt more tired and cramped, trimmed more.
M-09	3	yaw control; roll control; pitch control; overall control sensitivity	Yaw, roll & pitch were all slightly more sensitive with some lag between input and airplane response.
M-10	3	roll control; pitch control; overall control sensitivity	Aircraft didn't seem as responsive, initially, creating overcontrol situations.

PF	Questionnaire	Control	Comment
M-11	3	yaw control; pitch control; overall control sensitivity	Yaw - I am still spending a lot of time watching slip indicator. Response seems to lag slightly for me. I'm a little behind wrt this. Pitch - Slightly heavy for me, but not much.
M-12	3	yaw control	Rudder feels slightly oversensitive.
M-13	3	yaw control; roll control; overall control sensitivity	As before, the sensitivity of the simulator seemed higher than the plane.
M-14	3	yaw control; roll control; pitch control; throttle control; overall control sensitivity	Just minor differences - nothing significant.
M-15	3	yaw control; pitch control; overall control sensitivity	Same as before.
M-16	3	yaw control; roll control; pitch control; overall control sensitivity	Seems like small inputs move sim a lot.
M-17	3	yaw control; pitch control	Sim sentivity [sic] w/o kinesthetics
M-18	3	yaw control; roll control; pitch control; overall control sensitivity	Same reason as previously stated. [In these sim you tend to overcompasate [sic] more than the airplane because sim is more light [sic] sensation. Airplane feels heavier.]
M-19	3	yaw control; roll control; pitch control; overall control sensitivity	I have to move the controls more in the sim than the a/c to get the same response. A/C is more solid when moving yoke for roll and rudders for yaw - Pitch is about the same.
NM-02	3	pitch control	Elevator control seemed less sensitive than the airplane in light turbulence.
NM-03	3	yaw control; roll control; pitch control; overall control sensitivity	Same coment [sic] - Limited response during initial portion of control actions.
NM-04	3	yaw control; roll control; pitch control	All yaw inputs generate exaggerated responses.
NM-05	3	yaw control; roll control; overall control sensitivity	Rudder very much more sensitive, aileron, lesser so.
NM-06	3	yaw control; roll control; overall control sensitivity	The rudders are more sensitive than the airplane.
NM-08	3	pitch control	Pitch somewhat sensitive.
NM-10	3	yaw control	Yaw control was slightly sensitive.
NM-10	3	throttle control	Throttle control - seemed more sensitive in fine tuning.

PF	Questionnaire	Control	Comment
NM-11	3	yaw control; roll control; pitch control; throttle control; overall control sensitivity	Just all around more sensitive, felt I was often over controlling.
NM-13	3	pitch control; throttle control	Just felt like pitch was more sensitive, throttles more direct response.
NM-14	3	yaw control; roll control; pitch control; overall control sensitivity	Still it seems like the sim is more responsive than the airplane.
NM-15	3	throttle control	Throttles: Require adjustment to maintain target airspeed.
NM-16	3	yaw control; roll control; pitch control; overall control sensitivity	The a/c tends to be a little more stable and requires more control input to affect an attitud [sic] change.
NM-17	3	pitch control	Pitch control appeared to hesitate some. Sluggish. Required more control and in some cases resulted in over control.
NM-18	3	yaw control; roll control; overall control sensitivity	Completly [sic] different senstivity [sic] than earlier and feels just a bit more sensitve [sic] than acft.
NM-19	3	yaw control; pitch control; overall control sensitivity	Controls just seem to be slightly more effective than A/C.
NM-20	3	yaw control; roll control	Both roll and yaw seem more sensitive than the aircraft especially yaw.
NM-21	3	yaw control; pitch control	With motion on, really noticed rudder inputs

APPENDIX 18. COMMENTS ON STRATEGY & TECHNIQUE[12]

PF	Questionnaire	Maneuver	Comment
M-01	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	You can fly the aircraft easier because you can feel the aircraft a lot better than the simulator.
M-04	1	engine cut at V1; engine cut at VR	Not experienced in a/c.
M-04	1	engine-out straight-in approach/landing	Again, difficult to compare. 90% of approaches in airplane performed w/ flt directors on.
M-06	1	engine-out straight-in approach/landing; engine-out sidestep landing	Sim seems more sensitive ie. looses[sic]/gains energy more quickly than plane. Upset has more effect in sim
M-07	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	No flight experience with engine failures.
M-08	1	engine-out straight-in approach/landing	Engine failure seemed to come from the 1 or 2 eng however it was the 3 or 4 that failed. [pilot may have given too much push]
M-08	1	engine cut at V1	Airplane tends to drift at a faster rate.
M-08	1	engine cut at VR	Parameters were very absolute.
M-10	1	engine-out straight-in approach/landing; engine-out sidestep landing	We tend to use autopilot more during [blown] engine approaches (F/Os usually turn off A/P after established on G/S.
M-12	1	engine cut at V1; engine cut at VR	Seemed to be too sensitive in yaw.
M-13	1	engine cut at V1; engine cut at VR	Have never performed "Non-LNAV" "Non-VNAV" takeoffs in line flying - so this had me "behind the airplane" from beginning of the takeoff.
M-16	1	engine-out straight-in approach/landing	Sensitive to inputs.
M-18	1	engine-out straight-in approach/landing; engine-out sidestep landing	these is [sic] slightly different because of the surprise of what happen [sic] F/D off suddenly
NM-01	1	engine cut at V1; engine cut at VR	Could be the amount of thrust i.e. Full thrust T/O or not knowing that the engine would fail.
NM-05	1	engine-out straight-in approach/landing	If you can fly sim a/c -- is easier to control [and] is more stable. [Also] a/c-responds slower than sim due to control lag - and physical domentions [sic].
NM-06	1	engine cut at VR	Airplane would [be] slower.
NM-06	1	engine-out sidestep landing	Sim to[o] quick to move.
NM-06	1	engine cut at V1	Airplane would be slower to move
NM-06	1	engine-out straight-in approach/landing	Airplane more stable.
NM-07	1	engine cut at V1	Unknown - but same as other simulators.

[12] Note that pilot NM-09 was excluded from all analyses because it was discovered only after his participation that he was not currently qualified on the B747-400 airplane. He was replaced by NM-21.

PF	Questionnaire	Maneuver	Comment
NM-07	1	engine cut at VR	Because no motion was felt throughout flight
NM-11	1	engine cut at VR	Only difference, I would level at 1000' AGL for clean up
NM-13	1	engine-out sidestep landing	Appeared to require more rud and ail input to comp for eng fail.
NM-14	1	engine cut at V1	Unable to detect the yaw until Hdg started to change. Therefore, a slower response time.
NM-14	1	engine-out straight-in approach/landing	The simulator seemed more sensitive regarding hdg, yaw. It required more sensitive control inputs.
NM-16	1	engine-out straight-in approach/landing	Found using "approach mode" on ND more comfortable with no FD.
NM-17	1	engine-out straight-in approach/landing	Power changes and subsequent yaw changes do not give the same physical feel in the seat of the pants.
NM-18	1	engine-out straight-in approach/landing; engine-out sidestep landing	I had to adapt to lack of F/D. It is very rare not to use F/D.
NM-19	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Never had a V1 cut in a/c.
NM-21	1	engine-out sidestep landing	I would load 36R on legs page in scratchpad, rather than FREQ/CRS on NAVRAD page.
M-02	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Strategy and technique were the same but effort was required to implement within the sim environment.
M-03	2	engine-out sidestep landing	Slight difference in roll felt. The sim is more sensitive
M-04	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Same
M-05	2	engine cut at V1	I feel the V1 cut at this weight and power would require more rudder.
M-07	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	I may unconsciously be adapting to the simulator characteristics, but don’t notice myself doing it.
M-08	2	engine-out straight-in approach/landing	Rudder input slightly heavier. Aircraft did not respond as quickly.
M-10	2	engine-out straight-in approach/landing; engine-out sidestep landing	While never experiencing either [of the landings], A/P use would have been different (but not much). Of course we would norm use F/D.

PF	Questionnaire	Maneuver	Comment
M-11	2	engine cut at V1	Rudder vs slip indicator confused me after liftoff. Thought I had right amount on liftoff but as it turns out, I had way too much.
M-13	2	engine cut at V1; engine cut at VR	This simulator seems to have a very good visual system. Specifically seeing the clouds go by out the side window was somewhat distracting - just like it would be in the real airplane -->Engine out, low altitude
M-14	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Again due to slight differences in control loading/sensitivity.
M-15	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Adjust techniques for overly sensitive controls.
M-16	2	engine-out straight-in approach/landing	Mainly microburst wasn't realistic.
M-18	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	You have to compensate more than the airplane because the sim tends to get you out [of] your parameter more faster [sic]. So you have to compensate for that in your strategy and technique. Note: Put it in another words [sic] if we have passengers on the sim they will get very sick faster.
M-19	2	engine cut at V1; engine cut at VR	Amount of rudder - it appears to me that I needed to keep changing the rudder inputs during the maneuver to keep wings level - even though my PWR didn't change. Affected my heading control.
M-19	2	engine-out straight-in approach/landing; engine-out sidestep landing	Rudder - During approach, I had to keep changing rudder inputs even though PWR didn't change.
NM-01	2	engine cut at V1; engine cut at VR	In A/C it is apperent [sic] which engine had [sic] failed. I would take a 100% rudder input and leave it for the 1st segmet [sic] of the manover [sic]. Here in this sim I had to constantly scan the yaw indicator.
NM-03	2	engine cut at V1; engine cut at VR	Aircraft I think would be more stable during maneuvers, especially during later part of maneuver. Initial simulator reaction seems normal.
NM-04	2	engine cut at V1; engine cut at VR	On T/O profiles, I used more aileron and less active rudder adjustments to compensate for yaw sensitivities. Even slight changes in thrust or rudder had large effects on yaw and heading.

PF	Questionnaire	Maneuver	Comment
NM-04	2	engine-out straight-in approach/landing; engine-out sidestep landing	Pretty much the same on the approaches. [On T/O profiles, I used more aileron and less active rudder adjustments to compensate for yaw sensitivities. Even slight changes in thrust or rudder had large effects on yaw and heading.]
NM-07	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	No Motion Felt
NM-08	2	engine-out straight-in approach/landing; engine-out sidestep landing	Pitch sensitivity higher in simulator than airplane
NM-14	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	The same strategy, except you have to pay more attention to staying in trim and maintaining the desired hdg. It seems that I was using both left and right rudder to stay in trim. Normally with an engine out situation only one of the rudders is used primarily.
NM-16	2	engine-out straight-in approach/landing; engine-out sidestep landing	On both I used less trim (elevator and rudder) because trim changes were hard to feel and created momentary instability. It was easier to trim approximately, then handfly corrections. The a/c is much easier to trim.
NM-16	2	engine cut at VR	In order to maintain heading and bank angle, I used both aileron & rudder upon identification of engine failure. In the a/c, I would control direction initially w/ aileron, then blend in rudder.
NM-17	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Other than use of flight director through all phases of flight, especially non normal situations, procedures and techniques are the same as the aircraft for all of these.
NM-18	2	engine cut at V1	ACFT seems to weather-vane dramatically at lift off.
NM-18	2	engine-out sidestep landing	Didn’t notice windshear just slight changes in A/S & G/S.
NM-19	2	engine-out sidestep landing	seemed to be better able to handle windshear, sim seemed to be more responsive.
NM-20	2	engine cut at VR	Not quite as much rapid aileron input to level wings
NM-21	2	engine cut at VR	I flew about 2-3 degrees above the pitch bar to slow to V2 (150 kts) while the sim commanded 160 Knots with the pitch bar and 150 with the speed bug
M-01	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	I knew somewhat as to what I might expect. That should have helped me.

PF	Questionnaire	Maneuver	Comment
M-02	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Only because I was behind on maneuver, so it was not the sim more or less, rather me adapting to catch up.
M-03	3	engine-out straight-in approach/landing	Felt yaw and roll more difficult to control in the simulation.
M-04	3	engine cut at VR; engine-out straight-in approach/landing	Required more finesse - more delicate handling.
M-07	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Seemed to need heavier control pressure and more attention/ scan to keep simulator on track. Even the flight director didn't seem to be as precise, would allow climb of 100', etc.
M-09	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Note: I have never flown the airplane with an engine out and have never sidestepped in the airplane.
M-10	3	engine-out straight-in approach/landing; engine-out sidestep landing	Slightly different due to use of equipment. I also tend not to use rudder trim during [blown] engine ops. (But, I have never actually accomplished any of the above situations in the acft).
M-11	3	engine cut at V1	My initial rudder correction on the runway becomes excessive @ liftoff. I usually overcorrect the opposite way and thus wing and rudder rock @ liftoff, then settle down.
M-12	3	engine-out sidestep landing	Ailerons in sim felt more effective than in airplane.
M-12	3	engine-out straight-in approach/landing	Simulator felt to be overly sensitive in pitch.
M-13	3	engine cut at V1; engine cut at VR	After the break, it seems as though I was behind the aircraft versus just before the break.
M-14	3	engine-out sidestep landing	Tried later deployment of gear & landing flaps.
M-15	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	same as before
M-16	3	engine-out straight-in approach/landing; engine-out sidestep landing	More sensitive to wind
M-18	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Same reason as previously stated. [In these sim you tend to overcompasate [sic] more than the airplane because sim is more light [sic] sensation. Airplane feels heavier.]
M-19	3	engine cut at V1; engine cut at VR	<u>Both, rudder inputs were NOT STABLE - Had to keep varying.</u>
NM-01	3	engine cut at V1	Yaw and skid indicator: The skid was too sensitive therefore I had to disregard.

PF	Questionnaire	Maneuver	Comment
NM-01	3	engine cut at VR	Its movement and use only trend movement of the yaw and skid indicator.
NM-04	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	As before, more active with aileron than rudder. (Id use more rudder, aileron as required in airplane, other sims).
NM-06	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Rudder to [sic] sensitive.
NM-11	3	engine cut at V1; engine cut at VR	Both, I was thinking "be very easy with the rudder"
NM-14	3	engine cut at V1; engine cut at VR	During V1 and VR cut it seems like the plane became uncoordinated very quickly. On initial application of the rudder it seemed to be too much, so I momentarily released rudder pressure and then had to reapply the same rudder.
NM-16	3	engine cut at VR	Initial cross control after engine failure. In a/c - aileron first/ then rudder.
NM-17	3	engine cut at VR	Without seat of pants cues correct the integration of instrument info was more difficult. [experimenter comment: motion was on during this phase]
NM-18	3	engine cut at V1	Overcontrolled initially.
NM-18	3	engine-out sidestep landing	More bumps needed (Turb)
NM-18	3	engine-out straight-in approach/landing	Still didn’t notice WShear.
NM-19	3	engine-out sidestep landing	Maneuvering seems easier - more responsive.
NM-20	3	engine cut at V1; engine cut at VR	Somewhat easier in the A/C Seat of pants yaw

APPENDIX 19. COMMENTS ON HANDLING QUALITIES[13]

PF	Questionnaire	Control	Comment
M-02	1	pitch control; yaw control; altitude control; overall handling qualities	The overall sensitivity of the sim makes the handling qualities moderately worse
M-03	1	pitch control; overall handling qualities	Pitch seems a little erratic in turns, felt a pitch up and down when initiating a turn. Altitude- felt it a little harder to maintain altitude in the sim. Pitch caused more airspeed change than I expected. Overall - I think the sim is more sensitive than the airplane in pitch.
M-04	1	pitch control; bank angle control; yaw control; heading control; airspeed control; overall handling qualities	Difficult to assess because most of sim flying was with eng-out configuration. Airspeed in simulator does not appear to react as quickly as in airplane.
M-07	1	pitch control; bank angle control; altitude control; heading control; airspeed control; overall handling qualities	Simulator easier to hold a specific airspeed/heading (seemed to drift off less).
M-08	1	pitch control; bank angle control; yaw control; altitude control; overall handling qualities	Slightly more sensitive.
M-09	1	pitch control; yaw control; altitude control; overall handling qualities	Pitch, yaw, altitude control are all stiffer and less responsive with a slight lag between input and output.
M-10	1	altitude control	Altitude control was very similar, but did seem to be a little easier (when my instrument cross check was up to speed.)
M-13	1	pitch control; bank angle control; yaw control; altitude control; heading control; airspeed control; overall handling qualities	In performing tasks, seems similar to airplane
M-14	1	pitch control; yaw control; altitude control; overall handling qualities	No significant change, just enough to feel different.
M-15	1	yaw control; overall handling qualities	Same rudder input made handling difficult.

[13] Note that pilot NM-09 was excluded from all analyses because it was discovered only after his participation that he was not currently qualified on the B747-400 airplane. He was replaced by NM-21.

PF	Questionnaire	Control	Comment
M-18	1	pitch control; bank angle control; yaw control; altitude control; overall handling qualities	See previous comment [In these sim you tend to overcompasate [sic] more than the airplane because sim is more light sensation. Airplane feels heavier. (This answer apply [sic] to other questions too).]
M-19	1	pitch control; yaw control; overall handling qualities	It appeared that the rudder inputs kept changing - it could have been me, but I thought I didn't change anything but I had to change the rudder input.
M-20	1	altitude control	There is less somatic feel (visual & seat of pants) for small deviations in the sim, than there is in the acft.
NM-02	1	altitude control	Pitch steering bars occasionally give erroneous commands - ie. Trying to keep level flight: I was allowed to deviate with no correcting commands
NM-03	1	pitch control; bank angle control; yaw control; altitude control; overall handling qualities	On subject approaches, raw data localizer control seemed moderately worse (Could be [my] scan).
NM-04	1	pitch control; bank angle control; yaw control; altitude control; heading control; airspeed control; overall handling qualities	"Slightly" worse overall should be emphasized.
NM-06	1	pitch control; yaw control; overall handling qualities	This sim is to [sic] quick to move - It will not stay in trim.
NM-07	1	bank angle control; yaw control; altitude control; overall handling qualities	Felt almost no motion
NM-08	1	pitch control	Too sensitive. Airplane tends to hold an established vertical rate.
NM-13	1	bank angle control	Less stable.
NM-14	1	yaw control; overall handling qualities	Again the yaw was much different. Also part of the problem might be that without the motion, you lose a large source of sensory information.
NM-15	1	pitch control; bank angle control; yaw control; overall handling qualities	Pitch/Bank/Yaw: More sensitive than the a/c (less stable). Overall: a bit unstable.
NM-16	1	pitch control; bank angle control; yaw control; altitude control; overall handling qualities	Lack of motion feeback [sic] makes performing tasks require greater concentration than the airplane. The simulator tends to seem less stable than the airplane. That may be as much a function of pilot over control due to lack of sensory input (ie. motion/sound)
NM-17	1	pitch control; yaw control; overall handling qualities	Again, the roll and pitch controls are mushier requiring over imput [sic] and subsequent correction to the over imput [sic].

PF	Questionnaire	Control	Comment
NM-18	1	yaw control	Yaw seemed more controllable than last ACFT once warmed up on this machine.
NM-19	1	pitch control; bank angle control; yaw control; altitude control; heading control	Yaw seems closer to sim than A/C. The sim handles well - maybe overall slightly better than A/C. The A/C somewhat sluggish handling qualities may make pilots a little too complacent regarding control usage in crosswinds, etc.
NM-20	1	yaw control; heading control; overall handling qualities	The sim is a little harder to control heading because of yaw/rudder sensitivity + lack of seat of pants yaw feel.
NM-21	1	pitch control; bank angle control; yaw control; altitude control; heading control; overall handling qualities	Motion off is disorienting and reduces feedback. My head was almost spinning once breaking out on the ILS
M-02	2	pitch control; bank angle control; yaw control	Mainly because the sim feel causes or can cause over controling [sic] more than the aircraft. For example, simulator feels like "weak lateral stability" rather than "strong lateral stability".
M-03	2	pitch control; bank angle control	Seems to be more sensitive than airplane.
M-04	2	altitude control	Slightly worse
M-04	2	airspeed control	Slightly worse - not as responsive to throttle inputs.
M-12	2	bank angle control	Ailerons slightly more sensitive than airplane.
M-12	2	yaw control	Rudder feels too sensitive.
M-13	2	pitch control; bank angle control; yaw control; altitude control; heading control; airspeed control	As previous, airplane seems to be more stable and "tighter" i.e. Seems to handle better
M-14	2	pitch control; bank angle control; yaw control; airspeed control	Due to slightly lighter control loading/sensitivity
M-15	2	pitch control; bank angle control; yaw control; altitude control; heading control	All are much more sensitive than the airplane. Much to [sic] rapid a response than the real plane.
M-16	2	pitch control; bank angle control; yaw control; altitude control; heading control; airspeed control	Not as stable of platform. Minor changes do a lot.
M-18	2	pitch control; altitude control; heading control	The airplane is most stable. Sim tends to go away from alt, hdg more quicker.

PF	Questionnaire	Control	Comment
NM-01	2	bank angle control	Difficult did not want to stay in one place, ie. seemed to precess [pilot said it was inherently unstable unlike the company simulator which is more stable than the aircraft]
NM-01	2	yaw control	Yaw indication moved around without input. In comparison the aircraft dampens response to controls and indicator.
NM-03	2	pitch control; bank angle control; yaw control; altitude control; heading control; airspeed control	"I think it should be slightly worse"
NM-04	2	yaw control	Yaw control sensitivity made heading/ yaw control very tough at first.
NM-04	2	heading control	Overall sim seems to handle like a much lighter airplane.
NM-05	2	pitch control	To [sic] light. Normal weights would help. Say-875,000.
NM-05	2	yaw control	To [sic] light.
NM-06	2	bank angle control; heading control	The sim is overall more sensitive than the airplane
NM-15	2	pitch control; bank angle control; yaw control; airspeed control	Axes control seems a bit "unstable". A/c tends to hold airspeed more precise than simulator.
NM-16	2	pitch control; yaw control	The lack of motion is a distraction. It takes away from the sensation of flight. The simulator definitely lacks the stability of the a/c. The slightest force on the controls causes often unwanted attitude changes however slight.
NM-18	2	yaw control	Too nice. I can't feel the tail move (skid)
NM-18	2	airspeed control	Might be too easy.
NM-21	2	heading control	Loc roll bar at capture was too sensitive and aggressive at Loc turnon [sic]
M-02	3	pitch control; bank angle control; yaw control	Slightly "worse" may be the wrong word - I would say "different"
M-03	3	pitch control; yaw control; overall handling qualities	Feel that the pitch and yaw are very sensitive.
M-04	3	pitch control; bank angle control; altitude control; overall handling qualities	Again, just seems like I had to stay "on top" of the simulator more than the airplane - less stable.
M-06	3	bank angle control	Just sensitive aileron. My slow cross-check.
M-07	3	pitch control; bank angle control; altitude control; heading control; airspeed control; overall handling qualities	Simulator felt heavy and sloppy, not responding as well as before lunch, needed more attention, as well as trim to fly on speed/altitude.

PF	Questionnaire	Control	Comment
M-09	3	pitch control; bank angle control; yaw control; altitude control; overall handling qualities	Slight lag between input and airplane response.
M-10	3	pitch control; bank angle control; altitude control; heading control; overall handling qualities	Once again, the sim seemed a little "stiffer" than aircraft and seemed to "bobble."
M-11	3	yaw control; overall handling qualities	Yaw - I do a lot of yaw watching. Yaw seems to lag wrt my inputs, but it is sensitive.
M-12	3	yaw control; airspeed control	Rudder slightly over sensitive. Airspeed easier to control than plane.
M-13	3	bank angle control; yaw control; overall handling qualities	In relation to sensitivity, the simulator does seem to be more difficult/ challenging than the actual aircraft.
M-14	3	pitch control; bank angle control; yaw control; altitude control; airspeed control; overall handling qualities	Again very minor excursions from baseline - Nothing significant.
M-15	3	pitch control; yaw control; heading control; overall handling qualities	Same as before.
M-17	3	pitch control; yaw control; airspeed control	Sim sentivity [sic] w/o kinesthetics
M-18	3	pitch control; bank angle control; yaw control; altitude control; heading control; airspeed control; overall handling qualities	Same reason as previously stated. [In these sim you tend to overcompasate [sic] more than the airplane because sim is more light [sic] sensation. Airplane feels heavier.]
M-19	3	pitch control; bank angle control; yaw control; heading control; airspeed control; overall handling qualities	Simulator is less stable than the airplane in terms of heading, altitude & yaw - Maintaining inputs once they are put in.
M-20	3	pitch control; bank angle control; heading control; overall handling qualities	The sim did not feel as crisp as the ACFT. Pitch, bank angle, and heading control (especially) felt mushy and imprecise.

PF	Questionnaire	Control	Comment
NM-03	3	pitch control; bank angle control; yaw control; altitude control; heading control; overall handling qualities	Overall stability (stay where you put and trim it). Aircraft more stable.
NM-04	3	pitch control; bank angle control; yaw control; altitude control; heading control; overall handling qualities	Sim handles like a lighter airplane.
NM-05	3	yaw control	Rudder too touchy.
NM-06	3	bank angle control; yaw control; overall handling qualities	I am having trouble with the rudder control in the sim.
NM-08	3	pitch control	Pitch sensitive in simulator.
NM-10	3	airspeed control	Airspeed control - seemed more difficult to fine tune.
NM-11	3	pitch control; bank angle control; yaw control; altitude control; heading control; overall handling qualities	The sim did not respond with the same sense of mass/inertia as the 550,000 lb aircraft would. Felt more like the old 727 sims.
NM-13	3	bank angle control; yaw control; airspeed control; overall handling qualities	Don’t feel as if--->After 3-4 hours in the sim, I have a "feel" for the sim. "Feels" like a/c very responsive to every input, but not overly sensitive.
NM-14	3	pitch control; bank angle control; yaw control; heading control; overall handling qualities	It feels like the airplane handles better ie. more responsive, but this creates added workload to maintain a constant attitude, and altitude. Airspeed control was most similar to the airplane.
NM-16	3	pitch control; yaw control; altitude control; overall handling qualities	The sensitivity of the controls and lack of stability make precision more difficult.
NM-17	3	altitude control; heading control; overall handling qualities	Altitude and heading control were a bit more difficult to maintain--Probably due to turbulance [sic] rather than sim function.
NM-18	3	yaw control; altitude control	Overall felt more sensitive. This may because of becoming accustomed to earlier feel.
NM-19	3	yaw control; altitude control; overall handling qualities	See previous [Controls just seem to be slightly more effective than A/C.]
NM-21	3	pitch control; yaw control; altitude control; overall handling qualities	Yaw seemed too touchy. Pitching down I didn't have the same sensation of less than 1g like in the airplane

APPENDIX 20. COMMENTS ON PERFORMANCE[14]

PF	Questionnaire	Maneuver	Comment
M-02	1	engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Simulators always have a different feel and cues to the aircrew cannot always be provided. The aircraft provides all those needed cues like sounds or actual motion.
M-03	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Straight in approach was off localizer farther with rudder trim out of position than I could feel in the airplane Eng out side step was again off localizer - didn’t have rudder trim set for the correction needed.
M-04	1	engine-out straight-in approach/landing; engine-out sidestep landing	E/O approach - pilot issue vrs sim.
M-06	1	engine cut at V1; engine-out straight-in approach/landing;	Raw data, coupled w/ the xtra cross-check usually results in a stagnated x check and more deviations, something not routinely flown or encouraged. So---it was less precise than I would prefer and w/ practice usually fly better.
M-07	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	No experience, but feel I may have done slightly better due to "seat of the pants" feel.
M-08	1	engine cut at VR	Could not see engine parameters on the upper EICAS to determine which engine had failed or what was going on with the primary instruments.
M-09	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Had difficulty coordinating aileron and rudder on engine cut at Vr.
M-10	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	While I hope my response would be similar (or perhaps better) in the aircraft, I have never actually experienced any of the above in the B747.
M-11	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Maybe I was getting used to sim flying. It takes a while to settle down & fly a simulator which is slightly more sensitive to my inputs.
M-13	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing	As described before, the Non-LNAV/Non-VNAV takeoff was difficult for me i.e. VNAV & autothrottles do much on an engine failure takeoff. Also... didn’t expect the lack of flight directors.

[14] Note that pilot NM-09 was excluded from all analyses because it was discovered only after his participation that he was not currently qualified on the B747-400 airplane. He was replaced by NM-21.

PF	Questionnaire	Maneuver	Comment
M-14	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Engine cuts: have not performed in sim since mid-May, none in actual aircraft. Approaches: Reliance on F.D., removal of FD at critical phase of phase (along with) A.P. required recueing [sic] of mindset.
M-15	1	engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Perceived rudder sensitivity made heading very difficult to hold-From there-speed & altitude deviations quickly followed.
M-16	1	engine-out straight-in approach/landing; engine-out sidestep landing	Sensitivety [sic] played a roll [sic] but not used to raw data approaches which played a big roll [sic].
M-17	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Power changes were more quick than my experience; therefore airspeed & pitch changes were rather abrupt and quickly materialized. This caused larger rudder & pitch adjustments - the former too light and quick - the latter too slow and heavy.
M-18	1	engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	See previous comment [In these sim you tend to overcompasate [sic] more than the airplane because sim is more light sensation. Airplane feels heavier. (This answer apply [sic] to other questions too).]
M-19	1	engine cut at V1; engine cut at VR	The rudder input differences caused (I think) a little more bank control problems than in A/C - Might have been due to the amount of deflection of Ball in respect to the heading indicator. [drawing of triangle with bar below with something sticking out from it towards the triangle versus triangle with bar below closer to center of triangle]
NM-03	1	engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	First engine out man performance is impacted by lack of normal prep and brief prior to initial take off.

PF	Questionnaire	Maneuver	Comment
NM-04	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	All these maneuvers have to be compared to other simulators, because I've never had any of above in the airplane. V1 cut - Wake-up call! Didn't restabilize on runway before rotation. VR cut - I let out too much rudder after initial response. Both cuts are worst case (max. thrust / light gross weight) On V1 cut climb-out, I fell behind on climb profile clean-up due to "A/T inop". I should have briefed/reviewed this more thoroughly (not a routine task at [airline company]) On engine out straight-in, got behind on no FD, No A/T approach. [Airline company] has 4000 RVR/ 3/4 mi visibility requirement for such approaches. According to my SOP, I should have gone around. This should be briefed more thoroughly with BO32 test crews.
NM-06	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	I would have crashed the airplane if I fly it like the sim.
NM-07	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Very little motion or no motion felt in sim.
NM-08	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Have not had actual V1 cut in airplane - [company] simulator only.
NM-10	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing	Honestly did not expect any of the event sets. Did not mental [sic] expect the unexpected so soon. 1. V1 cut- took me a bit to get a handle on the rudder. 2. VR cut- took me a bit to get the pitch under control. 3. Straight-in- took me sometime [sic] to get the raw data scan going. Did not expect FD to be turned off. Additionally, once I got visual, I was working lineup and lost the descent rate. As a result I got high and had to exceed 1000 fpm for landing. -Landed in touchdown zone but long at about 2700 down RWY. 4.
NM-10	1	engine-out sidestep landing	Sidestep- I would hope this would be like the a/c.
NM-11	1	engine cut at V1	I think on the V1 cut I allowed more heading deviation from centerline than I would like.

PF	Questionnaire	Maneuver	Comment
NM-12	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	A little caught off guard with respect to the engine failures. Unfamiliarity and foreign setting contributed.
NM-13	1	engine cut at VR; engine-out sidestep landing	Did not aggressively put enough rudder to maintain C/L. (VR) A/C req'd more initial control input to begin sidestep and then I failed to bring it back in line before overshooting R/W.
NM-14	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Harder to detect engine failures which slowed down the response times. No motion and sound contributed to the quality of performance. Also on the sidestep procedure we had a slight wind sheer [sic] situation which resulted in us remaining high. This was not expected by the weather reports.
NM-15	1	engine cut at V1; engine cut at VR	V1/VR cut: Action in sim is much "faster" (ie. quick yaw after failure.)
NM-16	1	engine-out straight-in approach/landing; engine-out sidestep landing	During straight approach, I felt I was chasing needles. Lack of motion sensation put me behind and I had to try to consciously speed up my scan.
NM-17	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	The seat of the pants physical cues and 3-D visual cues on breakout give a better feel for correction of errors. These added two cues help me refine what my instruments are telling me.
NM-18	1	engine-out straight-in approach/landing	EO ST IN APP [Engine out straight in approach]: MIS-SES DA on F/D out APP led to go around at 600ft. [from PNF: misunderstanding on MDA/DH (minimums) & started go around early]
NM-19	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Couldn't seem to pick up cues - Visual seemed ok but feel was less than I expected (mainly yaw) for V1, VR cuts. Sidestep was ok but I didn't get the usual cues from crosswind I'm used to--seemed that drift perception was subdued somewhat.
NM-20	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	With the nose up + few vis[ual] references the lack of yaw feel + extra sensitivity makes the VR cut harder in the sim. The V1 cut w/ center line info makes the yaw easier to solve on V1 cut + approaches
NM-21	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Lack of motion and FD's off at no notice was surprising and created some difficulty. Also I use the flight path vector in the airplane for 3o glidepath assistance.

PF	Questionnaire	Maneuver	Comment
M-01	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	I feel there are more clues in the aircraft into what is occurring. This fact helps reduce the work load as you don't get so far off your a/s [airspeed], alt, G/s, & LOC.
M-02	3	engine cut at V1; engine cut at VR	Behind the aircraft at first.
M-03	3	engine-out straight-in approach/landing; engine-out sidestep landing	Felt more visual clues in the airplane would help on flying the approach. Feel acceleration and turn forces better in the airplane.
M-04	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing	Felt the simulator required more constant attention than the airplane. If you looked away for a moment, the simulator rapidly became out of position.
M-06	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Slower cross check Could not find correct trim for rudder which caused me to drop items from my cross check then have to correct.
M-07	3	engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Although I felt controls were slightly degraded/sloppy/heavy, I was experienced and could deal with problems better except for Vr cut - surprised me.
M-09	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Sims are harder to fly than airplane but I have never flown airplane with engine out.
M-10	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	As previously stated, I have never accomplished any of the above, but aircraft seems more stable.
M-11	3	engine cut at V1; engine cut at VR	I think my trouble with V1 cut/ VR cut is pilot induced. Getting better w/ time in the sim.
M-12	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing	I felt my performance was worse overall after the break.
M-13	3	engine cut at V1; engine cut at VR	I felt very behind the airplane after lunch - somewhat "out of the loop"
M-14	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Definite impact of fatigue from jetlag (trans pacific crossing day prior) affecting problem recognition/solution time interval
M-15	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Sensitivity and lack of feedback in "seat of the pants" feel makes flying the sim much harder than the real airplane.
M-16	3	engine-out straight-in approach/landing; engine-out sidestep landing	Don't practice this type of flying.
M-17	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing	Scan needs & sim feel without kinesthics [sic] of a/c.

PF	Questionnaire	Maneuver	Comment
M-18	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	After the break and because [of] the lunch my performance felt I [sic] little worse. My concentration and scanning were different. Needed more time to concentrate.
M-19	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	My rudder control is better in airplane. My overall approaches are more stable.
NM-01	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	I just completed my annual check with no problems. I flew much better then (15-Mar-02). Airspeed control is easier. But most of all, yaw control is easier in the aircraft or the [company] sim than the NASA sim.
NM-04	3	engine cut at V1	(Again, compared to other sims only.) V1 cut - First response was ok. But even slight rudder recorrections created excessive excursions in yaw, roll.
NM-04	3	engine cut at VR	(Again, compared to other sims only.) VR cut - Same but I managed it better. [First response was ok. But even slight rudder recorrections created excessive excursions in yaw, roll.].
NM-04	3	engine-out straight-in approach/landing	(Again, compared to other sims only.) Straight-In App - Got away from me in close. Out of parameters from breakout to flare.
NM-04	3	engine-out sidestep landing	(Again, compared to other sims only.) Side-Step - Got high on sidestep.
NM-06	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	[Slightly worse] because of lack of cues.
NM-10	3	engine cut at V1; engine cut at VR	V1 and VR cut - Since I felt funky, I did not have a warm and fuzzy. I seemed to do well, but short of feeling funky, I expect I would have done better.
NM-10	3	engine-out sidestep landing	Engine out sidestep landing - I got some deviations during the sidestep maneuver [sic] since my Flight Director was still on and not giving me good information. I had Tom turn it off and things settled down.
NM-13	3	engine cut at VR; engine-out sidestep landing	Sim feels "heavier" - Control input is put in and sim is stable with little or no wandering.

PF	Questionnaire	Maneuver	Comment
NM-14	3	engine cut at V1; engine-out straight-in approach/landing	The sim still feels a little too light and responsive. On application of the rudder during the V1 cut it takes a couple of moments to take effect. But overall, the sim is performing more like the plane [than this morning.]
NM-16	3	engine cut at V1; engine cut at VR; engine-out sidestep landing	V1 cut easier due to heightened anticipation. V2 cut worse due to using rudder with aileron rather than aileron then rudder. Sidestep harder due to less visual cues and the lower level of stability of the simulator.
NM-17	3	engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Seat of the pants feel still lacking somewhat. Especially on VR cut and windshear scenario. Felt my body would give me cues to assist me in instrument interpretation.
NM-18	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	See [seem] to have lost accurate feel for acft. It will be interesting to see how my next acft flt goes. I'd be glad to follow up with my impressions once I fly again.
NM-19	3	engine-out sidestep landing	Better cues seemingly visual and maybe instruments - i.e. more responsive trend arrow or faster response of A/S and/or Rate of climb. Beats me!
NM-20	3	engine cut at V1; engine cut at VR	Was having harder time than training in solving yaw and keeping it solved.

APPENDIX 21. COMMENTS ON OTHER CUES[15]

PF	Questionnaire	Maneuver	Comment
M-03	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	NOTE: The sim always feels different for me than the airplane in roll during a visual maneuver. It seems more sensitive
M-04	1	engine-out straight-in approach/landing	Same comments as prev. [Again, difficult to compare. 90% of approaches in airplane performed w/ flt directors on.]
M-04	1	engine cut at V1; engine cut at VR	Same comments as prev. [Not experienced in aircraft.]
M-05	1	engine cut at V1	2nd V1 Cut ATIS & fog however I counted 3 lights [approximately] 600 ft RVR [runway visual range].
M-07	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	?No inflight experience with eng. failure- I imagine it would be slightly different in terms of feel and noise(?)
M-09	1	engine cut at V1; engine cut at VR	Rudder not as effective.
M-09	1	engine-out straight-in approach/landing; engine-out sidestep landing	Rudder response time delayed.
M-10	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Most all clues good, but can't replace actual [vibrations (illegible, pilot clarified to experimenter)] / sound.
M-12	1	engine cut at V1; engine cut at VR	Too sensitive to rudder input
M-13	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Only other difference noted was the NAV display seemed "jumpy"
M-15	1	engine cut at V1; engine cut at VR	Outside visual references are not good enough to give the same feel as airplane.
M-15	1	engine-out straight-in approach/landing; engine-out sidestep landing	Ground visuals & lack of feel both laterally & horizontally make visual flying very difficult
M-17	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Remember that none of these have I actually experienced in the airplane.
M-18	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	The noise level in sim are [sic] usually more pronounce [sic] and no [sic] that realistic. The 747-400 is a noisy airplane. It seems that the noise and feeling on all sim [sic] (767, A-320 etc) are not different from the 747. I think that should be something to compensate according to specific aircraft.

[15] Note that pilot NM-09 was excluded from all analyses because it was discovered only after his participation that he was not currently qualified on the B747-400 airplane. He was replaced by NM-21.

PF	Questionnaire	Maneuver	Comment
M-18	1	engine cut at V1	The noise cue are [sic] very different than airplane.
M-19	1	engine cut at V1; engine cut at VR	Rudder indication "ball" [picture of triangle with band below, arrow to band] was very sensitive compared to [company] a/c [aircraft].
NM-01	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Not as much motion visual cue's [sic]
NM-02	1	engine cut at V1; engine cut at VR	I'm sure a V1 cut in the real airplane would offer better visual cues, ie) yaw: possibly a better visual reference as to what is going on.
NM-04	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Motion response to an [sic] control inputs were non-existant [sic], particularly on large scale events/ inputs. (Eng. failures, landing, rapid control inputs)
NM-05	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Same as other sims. Never had a V1 or Vr failure.
NM-06	1	engine cut at V1	Airplane will give cues (feel, noise.) Normal.
NM-06	1	engine cut at VR	Airplane will give you cues (feel/noise) More cues in airplane.
NM-06	1	engine-out straight-in approach/landing; engine-out sidestep landing	More stable in airplane.
NM-07	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Very little motion felt if any.
NM-10	1	engine-out straight-in approach/landing	Not much depth perception so got high - landed long. Typical even in [company Boeing 747-]400 simulators.
NM-11	1	engine cut at VR	No "G" changes, of course. I think yaw sensation in aircraft would be much stronger
NM-12	1	engine cut at V1; engine cut at VR	More side vision cues [in airplane]. Other crew members
NM-14	1	engine cut at VR	Easier [than V1] to detect because the pilot has transitioned his scan to inside the a/c. [Pilot said VR was still different than the airplane because of lack of motion and sound.]
NM-14	1	engine cut at V1	No feeling due to no motion in sim. The engine cut was silent and harder to detect.
NM-16	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	No Motion Sensation

PF	Questionnaire	Maneuver	Comment
NM-17	1	engine-out straight-in approach/landing; engine-out sidestep landing	3D cues on breakout in low visibility are slightly better in the real aircraft.
NM-18	1	engine cut at V1; engine cut at VR	Lack of good yaw sense made both manuevers (sic) less accurate.
NM-18	1	engine-out straight-in approach/landing	Not much (air) feel. Bumps etc.
NM-19	1	engine cut at V1; engine cut at VR	I expected greater yaw at eng failure
NM-19	1	engine-out sidestep landing	Sim seemed to present cues faster (?) than real life situation.
NM-20	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Lack of yaw feel
M-01	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	easier to feel what the aircraft is doing vs simulator
M-02	2	engine-out sidestep landing	Microburst: I would have felt much faster the effect of microburst in throttle positions and quick attitude changes.
M-02	2	engine-out straight-in approach/landing	Shifting winds: I would have felt much sooner the dynamics of constant shifting winds.
M-03	2	engine-out sidestep landing	I have more visual & feel cues in the airplane
M-07	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	I imagine it would be close to that experienced in the simulator.
M-09	2	engine-out straight-in approach/landing; engine-out sidestep landing	Note: I have never done any engine out in the airplane.
M-10	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Sims do a pretty good job, but the sounds and vibrations are slightly diferent [sic].
M-13	2	engine cut at V1; engine cut at VR	As previous, visual system seemed to add real life distractions
M-14	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Slight difference in visual maneuvers primarily relating to visual cues (or lack thereof) normally associated with actual aircraft.
M-15	2	engine cut at V1; engine cut at VR	Outside visual doesn't give exact visual cues on takeoff
M-15	2	engine-out straight-in approach/landing; engine-out sidestep landing	No feel for sink rate or lateral movement
M-16	2	engine-out straight-in approach/landing; engine-out sidestep landing	Sensitivity & wind

PF	Questionnaire	Maneuver	Comment
M-18	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	as previously stated on the previous survey [The noise level in sim are [sic] usually more pronounce [sic] and no [sic] that realistic. The 747-400 is a noisy airplane. It seems that the noise and feeling on all sim [sic] (767, A-320 etc) are not different from the 747. I think that should be something to compensate according to specific aircraft.]
M-19	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	PFD refresh rate is too slow.
M-19	2	engine cut at V1; engine cut at VR	Rudder response.
NM-01	2	engine cut at V1; engine cut at VR	There seemed to be less motion
NM-01	2	engine-out straight-in approach/landing; engine-out sidestep landing	I was not sure the motion was on
NM-02	2	engine cut at V1; engine cut at VR	PROBABLY BETTER YAW feel in aircraft when you would lose an engine?
NM-04	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Again motion was ineffective as a cue for any maneuver.
NM-05	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	No ground feel. Only indicaton [sic] of landing is spoiler.
NM-05	2	engine cut at V1; engine cut at VR	No feel.
NM-06	2	engine cut at V1; engine cut at VR	No external cues - No noise. No feeling. The only thing that's telling me what the aircraft is doing is the flight instruments.
NM-06	2	engine-out straight-in approach/landing	No feel at touchdown.
NM-07	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	No Motion Felt
NM-08	2	engine cut at V1; engine cut at VR	Did not feel yaw
NM-10	2	engine cut at V1	Engine cut at V1: At [airline company] we train with "noise". Specifically an engine failure noise at the failure time. At [airline company] we use engine seizure so we here [sic] the noise. Additionally the weight is lighter than normal training but I am getting a feel. Also we do not use the screens as debriefing aids but I found them very helpful.

PF	Questionnaire	Maneuver	Comment
NM-10	2	engine cut at VR	Engine cut at V2-"Noise" primary difference.
NM-11	2	engine-out straight-in approach/landing; engine-out sidestep landing	For both [landings], simulator balloons when flaps selected from 10 to 20. Also pitches up a little. I think the aircraft actually noses over on this configuration change.
NM-12	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	In general there are additional visual cues in respect to side vision (additional windows).
NM-14	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	In all situations there were less clues or cues to help identify the malfunction. -(Yaw- lack of feeling, when in the side-step procedure the windsheer [sic] is very smooth and you dont [sic] notice the airspeed green arrow increasing right away. What you first notice is the glideslope falling away. "lack of descent."
NM-16	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	In all cases, small changes in attitude are difficult to detect by feel in the simulator like they can be in the aircraft. Sound in the a/c is also a help. You can hear very subtle changes in air noise in the a/c. You can also feel changes in speed in the aircraft.
NM-17	2	engine-out straight-in approach/landing; engine-out sidestep landing	3D cues in a real environment add into the mix for better control and corrections.
NM-18	2	engine cut at V1; engine cut at VR	Cant [sic] feel the bumps on runway. Also yaw was not perceptible.
NM-18	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	The motion was not perceptible during many of these manuevers [sic].
NM-18	2	engine-out sidestep landing	Windshear was not noticeable and certainly did not require evasive action. (More Turb.)
NM-18	2	engine-out straight-in approach/landing	Cant [sic] feel the bumps in the air. (Turb)
NM-19	2	engine-out sidestep landing	Windshear cues seemed more rapidly displayed on instruments.
NM-20	2	engine cut at V1; engine cut at VR	Lack of seat of pants yaw.
NM-21	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Lack of motion required more focus
M-01	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	There seems to be more clues as to what is occurring in the aircraft vs. the simulator

PF	Questionnaire	Maneuver	Comment
M-03	3	engine-out straight-in approach/landing; engine-out sidestep landing	Transitioning to visual difficult in the sim with roll and pitch more sensitive.
M-06	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Wind noise seems louder than in airplane.
M-07	3	engine cut at V1; engine cut at VR	I imagine different yaw & noise cues for both
M-09	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	I have never flown airplane with engine out and never sidestepped. Yaw can not be felt in sim, wind noise is different. There is a lag between control input and sim response.
M-10	3	engine cut at V1; engine cut at VR	Cues are not exactltly [sic] same - - Good cues just different
M-10	3	engine-out straight-in approach/landing; engine-out sidestep landing	Seemed like the acft was on the tip of a rod & seemed to "bobble" on occasion.
M-13	3	engine cut at VR	Visual in simulator makes it seem more like the airplane.
M-14	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Outside visual cues as mentioned before. [Slight difference in visual maneuvers primarily relating to visual cues (or lack thereof) normally associated with actual aircraft.]
M-15	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	same as before
M-18	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Same reason as previously stated. [In these sim you tend to overcompasate [sic] more than the airplane because sim is more light [sic] sensation. Airplane feels heavier.] But it seems that the noise of the engines sounded more pronounce [sic].
NM-01	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Except for visual cues.
NM-02	3	engine cut at V1; engine cut at VR	Engine cuts - hard to feel the yaw.
NM-04	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Can only compare to other sims. Never did any of these maneuvers in airplane. Exagerated [sic] yaw sensitivity resulted in excessive movement cues (transitory).
NM-05	3	engine cut at V1; engine cut at VR	Unable to simulate exact motion of aircraft.
NM-06	3	engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	I would have cues in the airplane [like] seat of the pants.
NM-06	3	engine cut at V1	I think the sim is acting quicker than the airplane.

PF	Questionnaire	Maneuver	Comment
NM-07	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Motion appeared to be on and functioning properly this session
NM-11	3	engine-out straight-in approach/landing; engine-out sidestep landing	The reaction to the shear was significant. The sim seemed to lurch/pitch
NM-12	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Other aural cues could contribute. We have 1000 ft calls, 500 ft calls, 100/50/20 calls.
NM-13	3	engine-out sidestep landing	Windshear on sidestep, if it is a "minimal" shear then sims [sic] is somewhat effective. However I feel the sim overcompensates for a shear that req's very little throttle or control input to correct shear
NM-14	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	With the addition of simulator motion there were more cues to help identify the malfunctions. It was helpful in all of the sequences. However the sim was still a little more tame than the airplane.
NM-16	3	engine cut at V1	Yaw easier to detect quickly in a/c.
NM-16	3	engine cut at VR	Fewer engine sounds than a/c.
NM-17	3	engine-out straight-in approach/landing; engine-out sidestep landing	Wheel touchdown feel was better so I was better able to judge my flare on the 2nd approach and maintained better directional control throughout landing roll.
NM-17	3	engine cut at VR	Seat of the pants cues were off.
NM-18	3	engine-out straight-in approach/landing	More bumps! & turb
NM-18	3	engine cut at V1	Inputs seemed exaggerated.
NM-18	3	engine-out sidestep landing	Seems pitch sensitive.
NM-19	3	engine-out sidestep landing	More stable, more maneuverable, but cues must contribute – don't know if it is visual or instrument response.
NM-20	3	engine cut at V1	Amount of rudder less.
NM-20	3	engine cut at VR	Yaw solution was harder.

APPENDIX 22. COMMENTS ON GAINING PROFICIENCY[16]

PF	Comment
M-01	About the same. The fact NASA doesn't follow all of [company] procedures changes the way I do things somewhat in the NASA simulator.
M-02	Gaining proficiency was about the same as the time in the simulator is increased. Both simulators take time to adjust to, so therefore, it reflects how much time a pilot has been in the simulator.
M-03	Felt a little distracted by my inability to compensate for changes in wind etc which made tracking localizer more difficult.
M-04	The conditions in the final sim period, more duplicate the performance of the previous experience with the [company] simulators, whereas earlier periods the NASA sim seemed much superior to the [company] sim experiences.
M-05	I feel they are the same.
M-06	No doubt about it. The less distracting it is to compare "airplane vs. simulator" hadling [sic] and the more closely the sims become to the plane the more practice (proficiency) one can attain out of the time spent in the sim. This simulator generally flies better than my last 400 simulator.
M-07	Before lunch, I felt the simulator was very close to [company] sims. After lunch, it felt like old technology, or purposely degraded stability.
M-08	Note w/o FD\ Auto-pilot is not SOP. Therefore, I had to relearn my scan!! Once that was accomplished no problem.
M-09	The simulator here and at [airline company] seemed identical to me.
M-10	I think it is an excellent simulator to gain proficiency on.
M-11	I feel I was gaining proficiency the same as I do in other sims.
M-12	They are both so close to the same I would judge them equal.
M-13	Training of quick repitition [sic] helped a great deal - lunch break did not.
M-14	Overall, more repetitions equals greater success. However, this was somewhat temporary by general feeling of fatigue (as discussed in previous critiques) which continued to progress as sessions went on
M-15	Pretty close to [company] sim - Perhaps rudder and elevator were a bit more sensitive than normal.
M-16	Seemed to improve with time.
M-17	Proficiency increase seemed fast at first then more rapid later.
M-18	There is not a significant difference between the two to make a comment.
M-19	It took a little longer for me to gain proficiency in the NASA sim than the [company] sim.
M-20	None.
NM-01	This sim view very much like the 767 [company] sim. I used strategies from that sim to gain proficiency here.
NM-02	Same
NM-03	Once you are familiar with simulator, proficiency can be gained normally.
NM-04	Well, I'm working harder to meet the parameters. So I'll do better elsewhere, but I still was rough on the yaw/heading control. It's harder to get proficient in this sim.
NM-05	Repitions, (sic) and time only way I know to become proficient.
NM-06	The proficiency gain in the NASA sim was about the same as in the [company] sim.
NM-07	Able to gain proficiency faster flying with the motion on. Less mental workload. Reduced reliance on instruments.
NM-08	The NASA simulator and the [company] simulator are very, very similar. I used the same techniques in both.
NM-10	The debrief screens used in the morning period were helpful in understanding how to improve performance.
NM-11	I felt I could gain proficiency during each session. It was a matter of "learning" the sim., which is what everyone does during annual/semi-annual training.
NM-12	I was able to gain proficiency in this simulator as well as my previous simulators.

[16] Note that pilot NM-09 was excluded from all analyses because it was discovered only after his participation that he was not currently qualified on the B747-400 airplane. He was replaced by NM-21.

PF	Comment
NM-13	With this last set up, no proficiency could be gained. Just a handful to fly it. Could generate no learning experience. Felt like ---->you didn't know if the sim was re-creating manual flying hazards or whether it was a sim glitch.
NM-14	This simulator felt similar to my previous simulator experiences. Small corrections had the predicted and desired result. The small corrections didn't have an aggressive unwanted result.
NM-15	Same
NM-16	The last session was a bit unproductive as the motion felt unusual. The upside was that I gained confidence in my ability to ignore sensations which conflicted with my instrument indications.
NM-17	The obvious closeness of control sensitivity and response to the aircraft will definitely aid in gaining faster proficiency in the aircraft.
NM-18	Just like gaining the feel for any new acft. Fortunately, all Boeings fly similarly. I've flown B707, 737, 777, 747. I felt I could gain proficiency at a normal rate.
NM-19	As I said previously, things just seemed easier in the NASA sim. But this is a no risk environment and much of the perceived "easiness" might by psychological.
NM-20	Can tell no differences between the two.
NM-21	No real difference with motion on.

APPENDIX 23. FINAL COMMENTS ACCEPTIBILITY

PF	Comment
M-01	Fine simulator.
M-02	As far as simulators I feel they are well above average to use as a training device. Even though the aircraft and simulator will always be slightly different it serves the purpose. However, if the pitch trim and rudder control and sensitivity could be improved that would be a great help.
M-03	Felt it is more sensitive once it goes into roll it almost feels like its hitting wind shear because the pitch changes so much.
M-04	Again, same thing. Earlier periods with NASA sim seem much better than the final NASA sim.
M-05	Very good.
M-06	Overall acceptability is above average. I would feel comfortable taking my annual evaluation in this simulator any day.
M-07	Due to my perceived degrading of stability, I would find it difficult to do much more than work at flying the simulator. I was becoming more comfortable, but never could relax.
M-08	Great training aid.
M-09	Excellent sim.
M-10	Good sim.
M-11	I think it was fine to teach me procedures and practice emergency procedures. My only gripe is spatial/ visual disorientation if I make too many corrections - inputs at once.
M-12	As good as present state of the art can produce.
M-13	As before, as good as any except - Nav display and engine instruments a little "jumpy". Visual system - very good.
M-14	Very comparable to most sims in [company] inventory.
M-15	A little more difficult to fly than the [company] sim do [sic] to increased sensitivity + waketurb + "burble" incorrect feel + design
M-16	Very good sim & instructors.
M-17	At the end better than the beginning At the end - acceptable.
M-18	It is an excellent simulator.
M-19	FINE - It was ok for a simulator and training tool. I would like better rudder feel for engine out work.
M-20	Great sim.
NM-01	As good as any I have flown. Although I would take a check ride in the [company] sim if I could choose.
NM-02	Great simulator.
NM-03	Overall totally acceptable - Some minor adjustments as discussed might be beneficial.
NM-04	Overall, it is pretty close to the fleet except as noted earlier.
NM-05	Very good simulator. Better with motion on, though
NM-06	It is a good fresh sim. The rudder problem is [sic] had [pilot's writing is illegible] problem.
NM-07	Very similar if not the same as [company] sims. Very acceptable for training.
NM-08	Increase volume on nose gear at landing and rollout. Decrease pitch sensitivity slightly.
NM-10	Simulator overall was completely acceptable.
NM-11	Sim is acceptable.
NM-12	Completely acceptable as an excellent flight training aid.
NM-13	Morning - excellent. - Afternoon - call maintenance. [maintenance was called, extensive testing on the motion found nothing wrong]
NM-14	This was the best sim session of the day.
NM-15	"Excellent"
NM-16	Other than the slightly unusual feel of the motion, the NASA sim was on par with other sims I've flown. All are acceptable for preparing fo [sic] initial operating flights in the a/c.
NM-17	Marked improvement over existing sims.
NM-18	Seemed "OK" but not real similar in the roll and yaw axis (Oversensitive yaw). Yaw was most inaccurate. Sometimes it felt like there was no yaw damper. Roll was not as sensitive as expected with the flaps down > 20.

PF	Comment
NM-19	Certainly as acceptable as any other sim I've used. (With comments previously stated concerning slightly better stability, better cues, and somewhat greater control sensitivity.
NM-20	This sim is very acceptable as to training.

APPENDIX 24. FINAL COMMENTS PHYSICAL COMFORT[17]

PF	Comment
M-01	Pretty much the same.
M-02	Same.
M-03	No difference.
M-04	The last period seemed about the same and perhap [sic] a bit worse than the previous [company] sim - However, the earlier periods in the NASA sim were much more comfortable with regard to nausia [sic], vertigo, motion, etc.
M-05	Same.
M-06	Physical comfort was fine. No symptoms noted. I could get clues, however, to when I had failed to use proper coordinated control inputs.
M-07	Seemed as comfortable - airflow, noise, headsets, visuals, instruments etc., all seemed about the same comfort level.
M-08	None.
M-09	See above [The simulator here and the one at [airline company] seemed identical to me]. NASA sim seems to have better air conditioning than [company simulator].
M-10	Well, since the last sim was a little more stable, there were occasions that I felt mild discomfort, but nothing degrading.
M-11	It seemed warm to me, but getting in the "hot seat" always makes one warm and sweaty. The sim was the same in this respect.
M-12	Same as above [they are both so close to the same I would judge them equal.]
M-13	Physical comfort good - I like using day mode with the lights turned up.
M-14	No comments.
M-15	Same except rudder/ yaw control loading seemed excessive.
M-16	About the same - good visual.
M-17	The same.
M-18	Physical comfort is not that difference between the two simulator.
M-19	Ok.
M-20	Very similar feel except for better visual in the clouds (as previously noted)
NM-01	The NASA sim was cleaner.
NM-02	Same.
NM-03	Generally seems to require a little more effort physically to maintain a given profile.
NM-04	With the motion dialed up, the excessive yaw sensitivity leads to some pretty big motion transients, which I believe are exagerated [sic]. This could create some discomfort.
NM-05	Same as other sims.
NM-06	I am dizzy and my body feels weak. I think I would be the same in any sim after that workout.
NM-07	Same - Very comfortable to me.
NM-08	Very comfortable/ same as [company] simulator.
NM-10	The first afternoon period I felt wacked out - wierd [sic] - funky. Other sessions in the morning nothing to note. The last afternoon period was not noticeable.
NM-11	Comfort was good. Never used my sweatshirt or got hot.
NM-12	Same as the previous simulators I have flown. No worse or better.
NM-13	Sim felt like it "free flowed" a lot more. Could make for some uneasy stomachs.
NM-14	The sims felt identical.
NM-15	Same
NM-16	The last session was the most disorienting, however, not overwhelming. Otherwise, the NASA sim had the same comfort level as previous sims that I have flown.
NM-17	The reduction in sim disorientation is a marked plus. The more comfortable one is with the realism of the training environment the better he will acquire and retain what he learns.

[17] Note that pilot NM-09 was excluded from all analyses because it was discovered only after his participation that he was not currently qualified on the B747-400 airplane. He was replaced by NM-21.

PF	Comment
NM-18	I felt comfortable by the final set. It is rather squarrozy compared to the aircraft but certainly manageable.
NM-19	See Above [As I said previously, things just seemed easier in the NASA sim. But this is a no risk environment and much of the perceived "easiness" might by psychological.]
NM-20	They are equal.
NM-21	Same when the motion is on.

APPENDIX 25. FINAL COMMENTS CONTROL FEEL, SENSITIVITY, OTHER CUES[18]

PF	Comment
M-01	The aircraft is easier to fly as there are more clues as to what is occurring. The simulator did a funny pitch at 1,000 AGL several times. The simulator is fairly realistic though and if you fly the simulator well you can fly the aircraft even better most of the time. JBC: With respect to other clues, the pilot also added that there were more in the aircraft, e.g., engine noise.
M-02	Overall by phase IV you forget the experience per say of the actual aircraft and concentrate on the control feel and sensitivity of the simulator. So, these elements were normal.
M-03	Felt sensitivity made it hard to correct for changes in yaw and pitch. It would be easier in the airplane to adjust changes in wind etc.
M-04	The final sim period, the feel, sensitivity felt worse than the earlier periods and worse than the airplane - significantly worse, expecially [sic] with regards to the pitch & aileron and throttle. Also, the control loading on the rudders [sic] seem too heavy.
M-05	No further comments.
M-06	Most sims I have ever flown never fly the same as the airplane. They are generally most sensitive in roll and rudder response to inputs. Pitch trim was normal. I feel that the "air noise" is louder in this simulator compared to the airplane for the same parameters and flight conditions
M-07	Perceived stability degradation in second half seemed to heighten workload to just fly the simulator. Not many brain cells left for working the engine problem etc. After t/o and climbout, the sim seemed to "bump" as if in mild turbulence and then seemed to start "wandering" becoming sloppy and harder to control.
M-08	Less visual cues, therefore more oscillation in turns, eng failures etc. Overall, good instrument cues for testing control sensitivity as it compared to airplane performance.
M-09	Pitch, yaw and roll are all harder to fly precisely than the airplane. All 3 plus the elevator trim seem to lag more than the airplane. Speed stability is more sensitive than the airplane. If you are level with power and speed stable and then enter a slight climb or descent, speed increases or decreases more rapidly than it would on the airplane. All controls feel somewhat heavier than the airplane.
M-10	The aircraft is more stable than the sim, but I think one learns more from an unstable platform. The visual on this sim is one of the best I've seen. - Good feel for flair [sic] alt & rate of decent [sic]. The airplane speed and heading control is better. One can usually look away for a second or two without losing control (no, it really wasn't that bad!) For a light aircraft, the engines didn't seem to respond as in the real acft/ [sic].
M-11	I find the simulator (as in all simulators) to be very sensitive and very slightly lagging behind my inputs. I think if you can fly the sim well, you can fly the airplane better. I [sic] always takes me a little while to get used to the sim. It's always a humbling experience (not necessarily a bad thing). I think the airplane is easier to fly, generally.
M-12	To me a simulator never feels exactly like the airplane. That means that to a great extent flying a simulator well means very quickly [determining] what the differences are. From that point on the problem is how to make the sim do what you want it to do.
M-13	Overall, compared to the airplane & other simulators I have been in, this simulator is as good as any in representing the airplane.
M-14	In general, control feel / sensitivity / loading felt slightly lighter than actual aircraft in all scenarios. Only exception was last session pitch trim requirements and pitch input requirements slightly higher. (In other words - Overall control pressure was more sensitive in nature than aircraft).
M-15	Simulator vs the airplane - Controls are way too sensitive. The false feeling burbles on the turns were not realistic- windshear example was not realistic with airplane experience- having no fly by the seat of your pants feel adds to difficulty in flying visuals - also yaw control loading seemed way over sensitive when moving rudders [sic] quickly
M-16	I feel I did better the last session got use to the sim & inputs - more relaxed.

[18] Note that pilot NM-09 was excluded from all analyses because it was discovered only after his participation that he was not currently qualified on the B747-400 airplane. He was replaced by NM-21.

PF	Comment
M-17	Feel and sensitivity seem light and quick respectively (especially yaw) but either became more similar to what I'm used to, or I got more adept.
M-18	This last session the simulator feel a little more heavier. But sensitivity is a more pronounce in the sim then in the airplane. Noise level seemed to be less than before.
M-19	Sim - Slop in the yoke. You can move the yoke a little before getting some reaction - In airplane you get instant reaction and no dead spots (or slop). Noise is good.
M-20	Sim behaved like aircraft as near as I could tell.
NM-01	I think the simulator motion input was increased on the last 2 periods. ELV [elevator] feel was difficult to estimate. The trim made no noise when running.
NM-02	Simulator is a little rough sometimes when you make aggressive inputs-the airplane is not quite as rough Throttles were a little sensitive - - maybe aircraft (simulator was light) Elevator was still a little heavy in light turbulence
NM-03	Feel in all axes of control seem slightly lighter than normal. Control sensitivity in pitch + roll seem slightly higher than normal, but this may be explained by lighter gross weights used in the scenario. Control sensitivity in yaw is much higher than normal. Based on control movements (rudder or aileron through adverse yaw), trim effects or asymetric [sic] thrust. It was very difficult to make subtle changes without over controlling, even with practice. Motion cues varied throughout the day, with motion cues being imperceptible in first 2 sessions. Overall fidelity of sim is directly proportional to motion.
NM-04	Feel in all axes of control seemed slightly lighter than norm. Control sensitivity in pitch and roll seemed slightly higher than normal. But this may be explained by lighter gross weights used in the scenario. Control sensitivity in yaw is much higher than normal. Based on control movements (rudder or aileron through adverse yaw), trim effects or asymmetric thrusts. It was very difficult to make subtle changes without over controlling. Even with practice. Motion cues varied throughout the day, with motion cues being imperceptible in 1st 2 sessions. Overall fidelity of sim is directly proportional to motion.
NM-05	Rudder still to sensitive, others are acceptable, far better than a few years back, but improvements are coming along. Again if you can fly the sim the airplane is a piece of cake.
NM-06	The control feel in the NASA sim is [?] than the [company] airpliain [sic].
NM-07	Same as aircraft.
NM-08	Overall feel of sim is very similar to the airplane. I found it somewhat more sensitive in pitch than the airplane. Visual system is very good
NM-10	The last period seemed a bit more pitch sensitive. In the afternoon I could hear and feel the landings whereas in the morning period I did not. I did not feel as funky in the very last event set. The noise was more noticeable/audible in the afternoon set.
NM-11	Simulator does not seem to decel when configuring for landing like the a/c does. In the a/c very little power corrections are needed from level altitude/cvean, Vzf +20 [?] to GS intercept/landing config. on glideslope. Final approach/flair [sic] seemed correct. On last session sim. would seem to pitch up or down while turning for no apparent reason.
NM-12	Compared to the airplane the simulator felt like most simulators relating to the airplane. More sensitivity, in the yaw (rudder) and the ailerons, especially. Pitch was good. Throttle response good.
NM-13	Overly sensitive, inputs were made and it felt like, little effect at first then inputs were overexaggerated later, sim felt very light and was constantly fighting it to fly it. From rudders, to trim everything.

PF	Comment
NM-14	This felt the most like the airplane. The cues provided helped identify the malfunctions. The controls felt heavy as they do in the airplane. Trimming is done more to releive [sic] control pressure than to maintain desired attitude. Without proper trimming the sim and plane feel very heavy making it uncomfortable.
NM-15	Simulator felt "sensitive" on controls (unstable about all three axes), otherwise similar to simulators at my company.
NM-16	In the last session during the take off phase, the control sensitivity seemed particularly high. I felt as though it was difficult not to overcontrol the aircraft. The control feel was reasonably normal. The rudder feel may have been a little light.
NM-17	Rudder control seemed stiffer in this last segment.
NM-18	Wow, not sure now what's real and what's not! The last ses seemed fairly familiar.
NM-19	Throttles in sim read about 1.20 EPR in same position throttles in A/C read 1.10 EPR. The NASA sim generally seems more responsive than [company] sims. In retrospect the control forces seem about the same but sensitivity is increased. The slip indicator is much more sensitive than [company] sims and A/C [aircraft]. Things (maneuvers) seem easier to accomplish in NASA sim. (I like the viz better, also).
NM-20	The same as previous surveys the rudder seems sensitive and control feel for rudder is slightly light. Pitch seems on except for short final.
NM-21	Felt several small pitch oscillates while hand flying turning to final at about 20 degrees of bank. Rudder seemed a little too sensitive, made the slip indicator dance around a lot.

APPENDIX 26. FINAL COMMENTS HANDLING QUALITIES, CONTROL STRATEGY[19]

PF	PNF	Questionnaire	Maneuver	Comment
M-03	PNF-1	2	engine-out sidestep landing	Very experienced. Above [ratings] is based on that.
M-06	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Seems to have better than average instrument cross check.
M-07	PNF-1	2	engine cut at VR; overall gain of proficiency	Wrong rudder on 2nd VR Cut. Overall gain average harder on average based on VR cuts
M-08	PNF-1	2	engine cut at V1	Gained proficiency as average except V1 cut which was much better improvement.
M-09	PNF-2	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Gained proficiency slightly easier, scan pattern increased.
M-10	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Big improvement over first attempt. Seems to have good instrument scan.
M-11	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Seems to have a bit more problem with rudder control on engine failures on take off. Instrumt [sic] scan on approaches is better than average. Above average approaches & landings.
M-12	PNF-2	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	P.F. began to get tired during last half of session.

[19] Note that pilot NM-09 was excluded from all analyses because it was discovered only after his participation that he was not currently qualified on the B747-400 airplane. He was replaced by NM-21.

PF	PNF	Questionnaire	Maneuver	Comment
M-13	PNF-2	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF has good x [cross] scan.
M-14	PNF-2	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF has good understanding of flight director use. I think PF became tired during final sequence & slightly overcontrol loc intercept, but a good job.
M-15	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good basic flying ability (instrument scan) allowed for above average improvement.
M-16	PNF-1	2	engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Has trouble with raw data approaches. Did not seem to be aware of wind direction/ velocity read-out on ND.
M-17	PNF-1	2	engine cut at V1; engine cut at VR; engine-out sidestep landing; overall gain of proficiency	Good scan and basic skills. One straight-in approach did not go too well but others were good.
M-19	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF started with good basic skills & scan to build on.
NM-02	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Has good cross check, particularly for getting as little flying as he does.
NM-05	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Average for experienced pilot.

PF	PNF	Questionnaire	Maneuver	Comment
NM-06	PNF-2	2	engine cut at VR; engine-out straight-in approach/landing; overall gain of proficiency	PF slow to increase scan pattern, therefore overcorrected & chased information.
NM-08	PNF-1	2	engine-out straight-in approach/landing; engine-out sidestep landing	Approach speeds are high without correction.
NM-10	PNF-2	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF is a current sim instructor.
NM-11	PNF-1	2	engine cut at V1; engine cut at VR	Gain in proficiency on engine cuts came as much from explaining/understanding F/D & what it commands for speed as flight practice. Good improvement in heading control with practice.(engine cuts)
NM-13	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good instrument scan & good basic skills.
NM-14	PNF-1	2	engine cut at V1; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good overall gain in proficiency. Crashed on 1st V1 cut. But got to average level after that. All approaches became above average, except last straight in approach.
NM-15	PNF-2	2	engine-out straight-in approach/landing	On ILS P.F. slightly slow on wind change on appch.
NM-16	PNF-2	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF has good scan pattern.
NM-17	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	On one VR cut simulator seemed to turn left for no apparent reason, before engine failure, sim was frozen, all others normal.

PF	PNF	Questionnaire	Maneuver	Comment
NM-18	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good basic flying skills and instrument scas [sic].
NM-19	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good scan and skills to start with, allowed good gain in prof. particularly with engine failures.
NM-21	PNF-2	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF is an instructor in simul.
M-03	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; overall gain of proficiency	Coming back after lunch seems to be hard. Seems to take time to get back up to speed.
M-06	PNF-1	3	engine cut at VR; engine-out straight-in approach/landing	In first engine cut and approach (VR & straight in) gain in proficiency was a bit below normal. Second circuit was average.
M-07	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Take offs about the same as start - (Approaches/Landings better) Used correct rudder inputs but a bit late.
M-08	PNF-1	3	engine cut at V1	Regressed on Engine Failure at V1.
M-10	PNF-1	3	engine cut at V1; engine cut at VR;	First after lunch, heading control on take offs with engine failures not as good as practice session - approaches were average
M-11	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good improvement in engine cuts. Continues to improve approaches.
M-12	PNF-2	3	engine-out straight-in approach/landing	PF slightly over controlled pitch on raw data ILS (after lunch).

PF	PNF	Questionnaire	Maneuver	Comment
M-14	PNF-2	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF seems to be a little tired, possible jet lag.
M-15	PNF-1	3	engine cut at VR	Engine cut at VR seemed to be a bit of a surprise.
M-16	PNF-1	3	engine-out straight-in approach/landing; overall gain of proficiency	Straight in approach is getting better but would still be a go around under normal conditions.
M-17	PNF-1	3	engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good inst. scan & basic abilities.
M-18	PNF-2	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF had slight lunch break letdown.
M-19	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF started with above average skills.
M-20	PNF-2	3	engine-out straight-in approach/landing	PF had slight let down on ILS approach (lunch).
NM-02	PNF-1	3	engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Above average skill in the begining [sic].
NM-05	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Has good cross check & is a bit further ahead of the aircraft than average.
NM-06	PNF-2	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Proficiency increaced [sic] at a normal rate from proficiency during training phase.

PF	PNF	Questionnaire	Maneuver	Comment
NM-08	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good overall improvement.
NM-11	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Has gained proficiency easier than average - better than average basic skills.
NM-13	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Improvement after the break better than average. Good basic flying skills & scan.
NM-14	PNF-1	3	engine-out straight-in approach/landing; engine-out sidestep landing	Engine failures acceptable, approaches good - PF seems to have good instrument scan.
NM-16	PNF-2	3	engine cut at VR	P.F. seem to over react to motion on VR cut. Improved quickly.
NM-17	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; overall gain of proficiency	Engine cut at V1 was better than VR cut. VR cut was almost crash. Not having motion washed out took PF by surprise. Speed on straight in approach was about 20 kts high--Side step approach was almost normal with speed about 10 kts high. Also on VR engine cut, believe PF initially applied wrong rudder
NM-18	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good basic flying skills & scan.
NM-19	PNF-1	3	engine cut at V1; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	VR cut was first take off - after that, PF got the "feel" of simulator somewhat better.
M-03	PNF-1	4	engine cut at VR; engine-out straight-in approach/landing; overall gain of proficiency	Seemed to do better in the morning.

PF	PNF	Questionnaire	Maneuver	Comment
M-06	PNF-1	4	engine cut at VR	Engine cut at Vr made harder by use of wrong rudder at engine failure. After recovery, average performance.
M-07	PNF-1	4	engine-out straight-in approach/landing; engine-out sidestep landing	Takeoffs average this time. Approaches above average.
M-09	PNF-2	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	P.F. has good scan & flying background.
M-11	PNF-1	4	engine-out straight-in approach/landing; engine-out sidestep landing	V1/ VR Cuts improved as average. Approaches improved better than average due good instrument scan.
M-12	PNF-2	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF I think was somewhat tired due to more raw data flying than normal.
M-13	PNF-2	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF may have become a little bored or tired during last two sessions.
M-14	PNF-2	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF I think was tired. (jet lag?)
M-18	PNF-2	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF flew this session without using rudder trim therefore tended to slightly overcontrol.
M-19	PNF-1	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Above average skills starting.

PF	PNF	Questionnaire	Maneuver	Comment
NM-02	PNF-1	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Pilot started from good level of proficiency. Gained proficiency as instrument flying basics were already good.
NM-05	PNF-1	4	engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	As before, good basic instrument cross-check makes improvement easier.
NM-08	PNF-1	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good gain in proficiency. Good basic flying ability - good scan.
NM-11	PNF-1	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good basic flying skills allowing better than average progress.
NM-13	PNF-1	4	engine cut at V1; engine cut at VR; engine-out sidestep landing; overall gain of proficiency	Good basic skills, & instrument scan. Backslid a little on straight in approach as speed got a little low.
NM-14	PNF-1	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Oscilation [sic] in roll much improved from previous. Seems to have good basic skills & be ahead of the aircraft.
NM-15	PNF-2	4	engine cut at V1; engine cut at VR	P.F. tends to allow a/c to drift off LOC/G.S. after visual contact with-out FLT DIR.
NM-16	PNF-2	4	engine cut at VR	P.F. still over controls on VR cut.
NM-17	PNF-1	4	engine-out sidestep landing	Speed control on straight-in landing was about the only problem this time.
NM-18	PNF-1	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good basic skills better than average instrument scan.

PF	PNF	Questionnaire	Maneuver	Comment
NM-19	PNF-1	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good scan and skills to start with.
NM-20	PNF-2	4	engine-out straight-in approach/landing;	PF overcontrol with full motion
NM-21	PNF-2	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	P.F. is siml [simulator] instru [instructor].

APPENDIX 27. FINAL COMMENTS GAINING PROFICIENCY[20]

PF	PNF	Questionnaire	Maneuver	Comment
M-03	PNF-1	2	engine-out sidestep landing	Very experienced. Above [ratings] is based on that.
M-06	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Seems to have better than average instrument cross check.
M-07	PNF-1	2	engine cut at VR; overall gain of proficiency	Wrong rudder on 2nd VR Cut. Overall gain average harder on average based on VR cuts
M-08	PNF-1	2	engine cut at V1	Gained proficiency as average except V1 cut which was much better improvement.
M-09	PNF-2	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Gained proficiency slightly easier, scan pattern increased.
M-10	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Big improvement over first attempt. Seems to have good instrument scan.
M-11	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Seems to have a bit more problem with rudder control on engine failures on take off. Instrumt [sic] scan on approaches is better than average. Above average approaches & landings.
M-12	PNF-2	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	P.F. began to get tired during last half of session.

[20] Note that pilot NM-09 was excluded from all analyses because it was discovered only after his participation that he was not currently qualified on the B747-400 airplane. He was replaced by NM-21.

PF	PNF	Questionnaire	Maneuver	Comment
M-13	PNF-2	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF has good x [cross] scan.
M-14	PNF-2	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF has good understanding of flight director use. I think PF became tired during final sequence & slightly overcontrol loc intercept, but a good job.
M-15	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good basic flying ability (instrument scan) allowed for above average improvement.
M-16	PNF-1	2	engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Has trouble with raw data approaches. Did not seem to be aware of wind direction/ velocity read-out on ND.
M-17	PNF-1	2	engine cut at V1; engine cut at VR; engine-out sidestep landing; overall gain of proficiency	Good scan and basic skills. One straight-in approach did not go too well but others were good.
M-19	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF started with good basic skills & scan to build on.
NM-02	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Has good cross check, particularly for getting as little flying as he does.
NM-05	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Average for experienced pilot.

PF	PNF	Questionnaire	Maneuver	Comment
NM-06	PNF-2	2	engine cut at VR; engine-out straight-in approach/landing; overall gain of proficiency	PF slow to increase scan pattern, therefore overcorrected & chased information.
NM-08	PNF-1	2	engine-out straight-in approach/landing; engine-out sidestep landing	Approach speeds are high without correction.
NM-10	PNF-2	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF is a current sim instructor.
NM-11	PNF-1	2	engine cut at V1; engine cut at VR	Gain in proficiency on engine cuts came as much from explaining/understanding F/D & what it commands for speed as flight practice. Good improvement in heading control with practice.(engine cuts)
NM-13	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good instrument scan & good basic skills.
NM-14	PNF-1	2	engine cut at V1; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good overall gain in proficiency. Crashed on 1st V1 cut. But got to average level after that. All approaches became above average, except last straight in approach.
NM-15	PNF-2	2	engine-out straight-in approach/landing	On ILS P.F. slightly slow on wind change on appch.
NM-16	PNF-2	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF has good scan pattern.
NM-17	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	On one VR cut simulator seemed to turn left for no apparent reason, before engine failure, sim was frozen, all others normal.

PF	PNF	Questionnaire	Maneuver	Comment
NM-18	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good basic flying skills and instrument scas [sic].
NM-19	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good scan and skills to start with, allowed good gain in prof. particularly with engine failures.
NM-21	PNF-2	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF is an instructor in simul.
M-03	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; overall gain of proficiency	Coming back after lunch seems to be hard. Seems to take time to get back up to speed.
M-06	PNF-1	3	engine cut at VR; engine-out straight-in approach/landing	In first engine cut and approach (VR & straight in) gain in proficiency was a bit below normal. Second circuit was average.
M-07	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Take offs about the same as start - (Approaches/Landings better) Used correct rudder inputs but a bit late.
M-08	PNF-1	3	engine cut at V1	Regressed on Engine Failure at V1.
M-10	PNF-1	3	engine cut at V1; engine cut at VR;	First after lunch, heading control on take offs with engine failures not as good as practice session - approaches were average
M-11	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good improvement in engine cuts. Continues to improve approaches.
M-12	PNF-2	3	engine-out straight-in approach/landing	PF slightly over controlled pitch on raw data ILS (after lunch).

PF	PNF	Questionnaire	Maneuver	Comment
M-14	PNF-2	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF seems to be a little tired, possible jet lag.
M-15	PNF-1	3	engine cut at VR	Engine cut at VR seemed to be a bit of a surprise.
M-16	PNF-1	3	engine-out straight-in approach/landing; overall gain of proficiency	Straight in approach is getting better but would still be a go around under normal conditions.
M-17	PNF-1	3	engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good inst. scan & basic abilities.
M-18	PNF-2	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF had slight lunch break letdown.
M-19	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF started with above average skills.
M-20	PNF-2	3	engine-out straight-in approach/landing	PF had slight let down on ILS approach (lunch).
NM-02	PNF-1	3	engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Above average skill in the begining [sic].
NM-05	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Has good cross check & is a bit further ahead of the aircraft than average.
NM-06	PNF-2	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Proficiency increaced [sic] at a normal rate from proficiency during training phase.

PF	PNF	Questionnaire	Maneuver	Comment
NM-08	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good overall improvement.
NM-11	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Has gained proficiency easier than average - better than average basic skills.
NM-13	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Improvement after the break better than average. Good basic flying skills & scan.
NM-14	PNF-1	3	engine-out straight-in approach/landing; engine-out sidestep landing	Engine failures acceptable, approaches good - PF seems to have good instrument scan.
NM-16	PNF-2	3	engine cut at VR	P.F. seem to over react to motion on VR cut. Improved quickly.
NM-17	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; overall gain of proficiency	Engine cut at V1 was better than VR cut. VR cut was almost crash. Not having motion washed out took PF by surprise. Speed on straight in approach was about 20 kts high--Side step approach was almost normal with speed about 10 kts high. Also on VR engine cut, believe PF initially applied wrong rudder
NM-18	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good basic flying skills & scan.
NM-19	PNF-1	3	engine cut at V1; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	VR cut was first take off - after that, PF got the "feel" of simulator somewhat better.
M-03	PNF-1	4	engine cut at VR; engine-out straight-in approach/landing; overall gain of proficiency	Seemed to do better in the morning.

PF	PNF	Questionnaire	Maneuver	Comment
M-06	PNF-1	4	engine cut at VR	Engine cut at Vr made harder by use of wrong rudder at engine failure. After recovery, average performance.
M-07	PNF-1	4	engine-out straight-in approach/landing; engine-out sidestep landing	Takeoffs average this time. Approaches above average.
M-09	PNF-2	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	P.F. has good scan & flying background.
M-11	PNF-1	4	engine-out straight-in approach/landing; engine-out sidestep landing	V1/ VR Cuts improved as average. Approaches improved better than average due good instrument scan.
M-12	PNF-2	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF I think was somewhat tired due to more raw data flying than normal.
M-13	PNF-2	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF may have become a little bored or tired during last two sessions.
M-14	PNF-2	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF I think was tired. (jet lag?)
M-18	PNF-2	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF flew this session without using rudder trim therefore tended to slightly overcontrol.
M-19	PNF-1	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Above average skills starting.

PF	PNF	Questionnaire	Maneuver	Comment
NM-02	PNF-1	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Pilot started from good level of proficiency. Gained proficiency as instrument flying basics were already good.
NM-05	PNF-1	4	engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	As before, good basic instrument cross-check makes improvement easier.
NM-08	PNF-1	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good gain in proficiency. Good basic flying ability - good scan.
NM-11	PNF-1	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good basic flying skills allowing better than average progress.
NM-13	PNF-1	4	engine cut at V1; engine cut at VR; engine-out sidestep landing; overall gain of proficiency	Good basic skills, & instrument scan. Backslid a little on straight in approach as speed got a little low.
NM-14	PNF-1	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Oscilation [sic] in roll much improved from previous. Seems to have good basic skills & be ahead of the aircraft.
NM-15	PNF-2	4	engine cut at V1; engine cut at VR	P.F. tends to allow a/c to drift off LOC/G.S. after visual contact with-out FLT DIR.
NM-16	PNF-2	4	engine cut at VR	P.F. still over controls on VR cut.
NM-17	PNF-1	4	engine-out sidestep landing	Speed control on straight-in landing was about the only problem this time.
NM-18	PNF-1	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good basic skills better than average instrument scan.

PF	PNF	Questionnaire	Maneuver	Comment
NM-19	PNF-1	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good scan and skills to start with.
NM-20	PNF-2	4	engine-out straight-in approach/landing;	PF overcontrol with full motion
NM-21	PNF-2	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	P.F. is siml [simulator] instru [instructor].

APPENDIX 28. FINAL COMMENTS MISCELLANEOUS

PF	Comment
M-02	FYI: Loc capture: The PFD was given correct loc information. However, when I put in a "wind correction course" that should have corrected course destination, I noticed that on the "ND" it actually parallels the course with no intercept heading at all. When I figured this out, I made the proper heading correction to stay on the loc. course. Due to the cross-wind problem. VR Cut: During Phase IV I thought the aircraft yawed to the right for a left engine out, but actually it yawed left for a right engine out. As a result, I applied the wrong rudder which causes the aircraft unusual attitude.
M-03	Enjoyed the practice on approaches. Thought the engine out feeling was very close to the airplane reaction would be. Thought tracking localizer more difficult and hard to control.
M-04	Scenarios are so challenging and require so much attention to be focused on the mission that it is difficult to be cognizant of the items we are asked to evaluate. Also, not knowing in advance what items we are going to be commenting on, it is hard to reconstitute in your mind how those items (components) performed.
M-07	Great facilities - Everyone is ready and works hard to make it an enjoyable, productive experience for the pilot - - Thanks!
M-08	Turn the lights up on the upper EICAS instruments.
M-10	Not knowing the full scope of the experiment, I'm not sure of other aspects. I know I appreciated the opportunity to fly a 747 sim for several hours. The folks conducting the experiment were very professional and assisted greatly in my being comfortable with the experience.
M-11	I’m not sure what you are doing exactly, except making me sweat (HA!) Actually I would like to hear about it and also debrief how I did. Thanks for the opportunity to fly the simulator. I love the practice that I don't get in the airplane. Would like to do it again. Also, its hard to remember what the last sim I flew was like so its hard to compare unless I just flew it.
M-12	My one missed approach felt like I was encountering a strong wind shear, which resulted in great increases in both airspeed and altitude
M-13	Lunch break killed my performance [pilot drew an unhappy face]
M-14	As sim technology continues to progress and improve, most noticeable absent feature is ground rush nominal to actual aircraft operations. Especially side windows.
M-16	Maybe start off using the F/D a little more at first - at least one approach.
M-17	Felt like I was flat footed at outset (Literally & figuratively!)
M-18	The experiment is very intensive. Even though you do same maneuvers over and over. It is very hard to become comfortable with the maneuvers even though you know what is going to happen. It is a well thought experiment. Congratulations.--------------
M-20	The NASA and [company] sims behavior in the V2 cut is something I've often questioned. Based on my experience in the Boeing KC-135 and actual V2 cuts, the simulators seem to require a much faster and more aggressive response in order to maintain sim control. I find it difficult to believe the aircraft would behave similarly. I have not had an actual engine failure in the 747 so it is hard for me to say. However, compared to an actual failure of an engine in a KC-135, the simulator "wraps up" tighter and faster than I would expect.
NM-02	Always treated great here!
NM-04	On in-briefing, emphasize that you don’t want us flying to company Ops - Specs (Visibility requirements) or SOPs (use of VNAV/VNAV)on takeoff, autothrottle use, flight director use etc). At [airline company], no VNAV takeoff are not done unless a system degrade requires it. In that case, Id be reviewing that profile carefully.
NM-05	I hope you get lots of useful data.
NM-06	We should have this type of workout at [airline company] for our P.I. CR.
NM-07	Good workout - Feel more proficient now by a great deal. Thank you very much for this opportunity.

PF	Comment
NM-08	Performance plots are helpful in bringing attention to areas that are out of limits ie) bank angle. The learning curve to improve instrument scan from raw data vs. flight director, auto throttle takes 6 to 9 approaches and landings. Some discussion of EPR (power) settings before flying would speed up the learning process.
NM-10	Very professionally executed from start to finish. Including the rental car/hotel arrangements. I feel that my professional abilities have been greatly expanded. Since this is a performance based profession, it is important to challenge yourself and grow professionally - That objective was accomplished today in this experiment.
NM-12	Nice group of people hosting the study. Thank you!
NM-13	Enjoyable.
NM-14	I enjoyed the atmosphere[sic]. I hope I was helpful.
NM-16	Without knowing the research goals of the testing, I have no comments on the experiment. A good dusting of the cobwebs for me though.
NM-17	Questions on questionnaires are a bit ambiguous could be a bit clearer. I finally caught on what was really being asked in the second or third set of questions. Specifically with regard to the sensitivety [sic] and control issues.
NM-18	Nice study. I must say that overall I feel less certain now about how the aircraft feels. I look forward to flying the airplane again to further evaluate this study. Id be happy to follow up once I fly again. Email: [email address] Thxs ws
NM-19	Sorry too tired to think! Very interesting maneuvers. I appreciated the opportunity to repeat maneuvers and see feedback. The feedback wasn't always what I expected. Thanks

APPENDIX 29. PNF COMMENTS ON MOTION[21]

PF	PNF	Questionnaire	Question	Subquestion	Comment
NM-10	PNF-2	3	control performance	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	P.F. somewhat surprised of control feel with motion on, so initially overcontroled [sic], but improved quickley [sic].
NM-15	PNF-2	3	control performance	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	P.F. slighly [sic] overcontroled [sic] with motion on intiality [sic], but improved quickly.
NM-16	PNF-2	3	control strategy and technique	engine cut at VR	Seem to over react to motion after lunch
NM-16	PNF-2	3	gaining proficiency	engine cut at VR	P.F. seem [sic] to over react to motion on VR cut Improved quickley [sic].
NM-17	PNF-1	3	gaining proficiency	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; overall gain of proficiency	Engine cut at V1 was better than VR cut. VR cut was almost crash. Not having motion washed out took PF by surprise. Speed on straight in approach was about 20 kts high--Side step approach was almost normal with speed about 10 kts high. Also on VR engine cut, believe PF initially applied wrong rudder
NM-20	PNF-2	3	control strategy and technique	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	In all mavn. [maneuvers] P.F. tended to overcontrol due to full motion.
NM-20	PNF-2	4	gaining proficiency	engine-out straight-in approach/landing;	PF overcontrol with full motion
NM-21	PNF-2	3	control strategy and technique	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	PF slightly overcontroled [sic] while getting feel with motion on.

[21] Note that pilot NM-09 was excluded from all analyses because it was discovered only after his participation that he was not currently qualified on the B747-400 airplane. He was replaced by NM-21.

APPENDIX 30. PNF COMMENTS ON PF PERFORMANCE

PF	PNF	Questionnaire	Maneuver	Comment
M-01	PNF-2	1	engine-out straight-in approach/landing	Almost average on PIA
M-02	PNF-2	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	PF Scan pattern very proficient.
M-03	PNF-1	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Level is average I would expect for first attempt.
M-04	PNF-2	1	engine cut at V1	Aborted after V1
M-10	PNF-1	1	engine-out straight-in approach/landing	Got loc full off on straight in approach.
M-15	PNF-1	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Average for first period.
NM-06	PNF-2	1	engine cut at VR; engine-out straight-in approach/landing	PF overcontrol due to slow scan pattern while flying raw data.
NM-14	PNF-1	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Average for first attempt.
NM-17	PNF-1	1	engine-out straight-in approach/landing	Lost scan on straight in approach towards the end (under 1000' AGL).
NM-18	PNF-1	1	engine-out straight-in approach/landing	Misunderstanding on MDA/DH and started go around early. Average up to that point.
M-03	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Average for experienced pilot in this aircraft.
M-06	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing	Refer to previous page [Seems to have better than average instrument cross check] good instrument cross-check.
M-17	PNF-1	2	engine-out straight-in approach/landing	Straight in approaches except for one was good the other two were better than average.
M-18	PNF-2	2	engine cut at V1; engine cut at VR	PF would have done better on eng cut but he antisipated [sic] which eng would fail & sometime [sic] put in incorrect rudder slightly.

PF	PNF	Questionnaire	Maneuver	Comment
NM-06	PNF-2	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing	See note Qu # 1 [PF slow to increase scan pattern, therefore overcorrected & chased information.]
NM-08	PNF-1	2	engine cut at V1; engine cut at VR	Average approach except speeds remain high.
NM-14	PNF-1	2	engine cut at V1; engine-out straight-in approach/landing; engine-out sidestep landing	First V1 cut-crashed. Became average level after that. Achieved above average level on approaches - Did backslide a bit on last straight in approach.
NM-17	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Scan seems a bit slow at times.
M-02	PNF-2	3	engine cut at VR	PF not mentally prepare [sic] for T.O.
M-03	PNF-1	3	engine cut at VR; engine-out straight-in approach/landing	Comments same as previous page. [Coming back after lunch seems to be hard. Seems to take time to get back up to speed.]
M-06	PNF-1	3	engine cut at VR; engine-out straight-in approach/landing	Learning took place between first & second circuits.
M-07	PNF-1	3	engine cut at VR	A bit late on rudder input on Vr cut.
M-08	PNF-1	3	engine cut at V1	Regressed on V1 engine failure
M-12	PNF-2	3	engine-out straight-in approach/landing	See previous comment [PF slightly over controlled pitch on raw data ILS (after lunch).]
M-18	PNF-2	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	PF slight over control, due to getting behind on scan, due to lunch break.
NM-04	PNF-2	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	P.F. experienced after lunch lull
NM-06	PNF-2	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	PF still tends to overcontrol.
NM-10	PNF-2	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	P.F. somewhat surprised of control feel with motion on, so initially overcontroled [sic], but improved quickley [sic].

PF	PNF	Questionnaire	Maneuver	Comment
NM-15	PNF-2	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	P.F. slighly [sic] overcontroled [sic] with motion on intiality [sic], but improved quickly.
NM-17	PNF-1	3	engine cut at VR; engine-out straight-in approach/landing;	Engine failure at VR - Aircraft generally out of control until at 3500' and 270 deg heading. Believe wrong rudder applied at first. On approaches, speed control lacking about 20 kts high on straight-in & 10 kts on side step.
M-02	PNF-2	4	engine cut at VR	2nd Vr Cut OK
M-03	PNF-1	4	engine cut at VR; engine-out straight-in approach/landing	Did well before lunch.
M-06	PNF-1	4	engine cut at VR	Use of wrong rudder at engine cut made performance below average.
NM-02	PNF-1	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	See previous comments [Pilot started from good level of proficiency. Gained proficiency as instrument flying basics were already good].
NM-05	PNF-1	4	engine-out straight-in approach/landing; engine-out sidestep landing	Raw data approaches better than average, pilot ahead, seems to be reacting to wind data & not just to needle displacement.
NM-17	PNF-1	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Once again, speed control on approach was the main problem.

APPENDIX 31. PNF COMMENTS ON PF'S STRATEGY[22]

PF	PNF	Questionnaire	Maneuver	Comment
M-06	PNF-1	1	engine-out sidestep landing	Used quite a bit more rudder trim, than necessary.
M-08	PNF-1	1	engine cut at V1	Crashed
M-08	PNF-1	1	engine-out straight-in approach/landing	Got behind a/c - scan pattern slow.
M-10	PNF-1	1	engine cut at V1; engine cut at VR	Doesn't use rudder trim.
M-10	PNF-1	1	engine-out straight-in approach/landing	Didn't use wind information.
M-13	PNF-2	1	engine cut at V1; engine cut at VR	PF turns A/C to 270 degrees before cleaning up flaps with eng failure.
M-15	PNF-1	1	engine-out straight-in approach/landing	Didn't use normal amount of rudder trim.
M-16	PNF-1	1	engine-out straight-in approach/landing	Didn't seem to use NAV display wind indication.
NM-08	PNF-1	1	engine cut at V1	Aborted
NM-11	PNF-1	1	engine cut at V1; engine cut at VR	Out of 1400' MSL accelerated & cleaned up aircraft as one would but looked through F/D so speeds will show high at this point.
NM-13	PNF-1	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	same as average on first attempt
NM-14	PNF-1	1	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing	Did not use rudder trim until side step approach.
NM-18	PNF-1	1	engine-out straight-in approach/landing	Started GA early due to misunderstanding of minimums. Average up to that point.
NM-19	PNF-1	1	engine-out straight-in approach/landing; engine-out sidestep landing	Good scan - raw data approaches better than average.
NM-20	PNF-2	1	engine cut at VR	PF turned autopilot on early without advising PNF. A/C was 2000MSL so I let it continue.
M-03	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Techniques (overall) were standard.
M-07	PNF-1	2	engine cut at VR	Wrong rudder on 2nd Vr cut - otherwise average performance.

[22] Note that pilot NM-09 was excluded from all analyses because it was discovered only after his participation that he was not currently qualified on the B747-400 airplane. He was replaced by NM-21.

PF	PNF	Questionnaire	Maneuver	Comment
M-08	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Instrument scan seems a little slower than the average that I have seen.
M-10	PNF-1	2	engine-out straight-in approach/landing; engine-out sidestep landing	Doesn't use rudder trim very much.
M-11	PNF-1	2	engine cut at V1; engine cut at VR	Technique on engine cuts - seemed to be behind the aircraft & over controlled to catch up.
M-12	PNF-2	2	engine-out straight-in approach/landing; engine-out sidestep landing	PF uses inboard REV only after landing (technique only).
M-14	PNF-2	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	PF uses rudder trim quite a bit, slightly more & quicker than the average PF.
M-16	PNF-1	2	engine-out straight-in approach/landing	Did not correct for wind chased LOC needle with big corrections.
M-20	PNF-2	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	P.F. flys [sic] with zero rudder trim & uses manual input. On appch P.F. flys [sic] with differential throtte [sic] position (i.e. outboad [sic] operating eng at idle).
NM-02	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Strategy same as average but cross check better than average resulting in above average performance.
NM-03	PNF-2	2	engine-out straight-in approach/landing; engine-out sidestep landing	P.F. controls speed using inboard throttles only, leaves outboard at approach power after landing, through landing roll
NM-06	PNF-2	2	engine cut at VR	PF initial rudder input wrong direction all 3 T.O. s
NM-06	PNF-2	2	engine-out straight-in approach/landing; engine-out sidestep landing	A/C in landing config outside Charr
NM-08	PNF-1	2	engine-out sidestep landing	Leaves approach speed high-otherwise average to above average
NM-16	PNF-2	2	engine-out straight-in approach/landing; engine-out sidestep landing	PF sets desired target speed below ref speed for current flap setting. PF uses ref + 10kt for app speed. So is constantly fast on final app.
NM-19	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Tech. & strat. same. PF just further ahead of a/craft than average.
M-03	PNF-1	3	engine cut at VR; engine-out straight-in approach/landing	See comments on first page [Coming back after lunch seems to be hard. Seems to take time to get back up to speed.] Pilot was not out ahead of the airplane & had trouble catching up.

PF	PNF	Questionnaire	Maneuver	Comment
M-05	PNF-2	3	engine cut at V1; engine cut at VR	P.F. climbed to 3500, began left turn to 270 degrees, then started flap retraction.
M-07	PNF-1	3	engine cut at VR	A bit late on rudder input.
M-08	PNF-1	3	engine cut at V1	Slow to recognize & correct.
M-10	PNF-1	3	engine-out straight-in approach/landing	Had good outboard engine reduced to lower power than inboard engines.
M-12	PNF-2	3	engine-out straight-in approach/landing	see previous [PF slightly over controlled pitch on raw data ILS (after lunch)]
M-13	PNF-2	3	engine cut at V1; engine cut at VR	PF appeared to try to antisapate [sic] eng failing, therefore slightly overcontrold [sic].
M-16	PNF-1	3	engine-out straight-in approach/landing	Behind the aircraft with wind corrections. Large heading changes but getting better.
M-18	PNF-2	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	See previous comments. [PF slight over control, due to getting behind on scan, due to lunch break.]
M-20	PNF-2	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	PF flys [sic] with split throttle thrust engine inop and uses no rudder trim.
NM-01	PNF-2	3	engine cut at VR	Not mentally prepared for T.O.
NM-03	PNF-2	3	engine-out straight-in approach/landing; engine-out sidestep landing	See Questionnaire #2 concerning Throttle usage on Approach + Landing [P.F. controls speed using inboard throttles only, leaves outboard at approach power after landing, through landing roll].
NM-06	PNF-2	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Cver controling [sic] all phases
NM-07	PNF-2	3	engine cut at V1	P.F. tends to use minimum rudder trim
NM-11	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Normal technique with better than average precision.
NM-14	PNF-1	3	engine-out straight-in approach/landing	Seemed average except did not use rudder trim.
NM-16	PNF-2	3	engine cut at VR	Seem to over react to motion after lunch

PF	PNF	Questionnaire	Maneuver	Comment
NM-17	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	PF scan is slow
NM-17	PNF-1	3	engine cut at VR	Believe wrong rudder applied initially and took a long time to recover.
NM-20	PNF-2	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	In all mavn. [maneuvers] P.F. tended to overcontrol due to full motion.
NM-21	PNF-2	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	PF slightly overcontroled [sic] while getting feel with motion on.
M-03	PNF-1	4	engine cut at VR; engine-out straight-in approach/landing	Strategy and technique involved overcorrecting indicating pilot was behind the aircraft during VR cut and straight in approach.
M-06	PNF-1	4	engine cut at VR	Initial use of wrong rudder.
M-11	PNF-1	4	engine cut at V1; engine cut at VR	Speed control will seem high as PF cleaned up airplane starting acceleration at 800' AGL.
M-18	PNF-2	4	engine-out straight-in approach/landing; engine-out sidestep landing	See previous comments. [PF flew this session without using rudder trim therefore tended to slightly overcontrol.]
M-19	PNF-1	4	engine-out sidestep landing	Seemed to anticipate wind shear & compensated more aggressively than one would expect in a real situation.
M-20	PNF-2	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	see previous comments [PF flys [sic] with split throttle thrust engine inop and uses no rudder trim.]
NM-02	PNF-1	4	engine cut at V1	Same strategy - Well done.
NM-03	PNF-2	4	engine-out straight-in approach/landing; engine-out sidestep landing	see Quest. #2 [P.F. controls speed using inboard throttles only, leaves outboard at approach power after landing, through landing roll]
NM-06	PNF-2	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Still over controls
NM-07	PNF-2	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	P.F. used minimum rudder trim while flying.

PF	PNF	Questionnaire	Maneuver	Comment
NM-11	PNF-1	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Normal technique/strategy, better than average precision.
NM-14	PNF-1	4	engine-out straight-in approach/landing; engine-out sidestep landing	Only small thing - Uses very little rudder trim with No. one engine shut down but a normal amount with No. four.
NM-21	PNF-2	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	P.F. hurried flt and tended to overcontrol, jerky flt controls to do so.

APPENDIX 32. PNF COMMENTS ON PF'S WORKLOAD[23]

PF	PNF	Questionnaire	Comment
M-06	PNF-1	1	On last approach -(sidestep)-had quite a bit more rudder trim than necessary which increased his workload.
M-07	PNF-1	1	Seemed a bit higher than average with rudder inputs. Not enough rudder at first, then over-did trim.
M-08	PNF-1	1	A bit higher than normal as instrument scan is a bit slow on some manuvers [sic].
M-10	PNF-1	1	Seemed a bit behind the airplane - Overcontrol in the begining [sic] - this improved on second takeoff/approach.
M-15	PNF-1	1	seemed a bit behind the aircraft with rudder inputs requiring more work with ailerons.
M-16	PNF-1	1	At this point, seems to be using larger than normal control inputs to achieve LOC/GS alignment.
M-19	PNF-1	1	Good basic flying skills and instrument scan. Makes the job look easy.
NM-02	PNF-1	1	Good Cross Check
NM-03	PNF-2	1	PF has flown siml. quite a lot. Is an instructor. I think.
NM-05	PNF-1	1	Approaches better or looked easier than average - good cross check.
NM-11	PNF-1	1	Good instrument scan allows PF to make approaches seem easy.
NM-15	PNF-2	1	Workload only slightly higher due to PF becoming accustom [sic] to slight differences in data display (ie Flt Dir).
NM-19	PNF-1	1	Good basic skills & instrument scan - makes the job look easy, particularly on raw data approaches.
M-03	PNF-1	2	Experienced pilot ahead of the airplane so he doesn't seem to work too hard.
M-04	PNF-2	2	P.F. appeared to begin to tire near end of secession [sic]
M-06	PNF-1	2	Good scan allowed him to seem like he was not working too hard.
M-08	PNF-1	2	Slow instrument scan makes him seem to work a bit harder than average.
M-10	PNF-1	2	Control inputs could be a bit smoother at times but generally average.
M-11	PNF-1	2	Slightly higher applies to engine cuts, on approaches, workload was lower was lower [sic] than average.
M-12	PNF-2	2	Workload increased in latter part on session due to fatigue setting in.
M-13	PNF-2	2	see previous comment [PF has good x scan]
M-15	PNF-1	2	Improved rudder control over first period.
M-16	PNF-1	2	A lot more control input, particularly in pitch, on approaches.
M-17	PNF-1	2	PF is ahead of the aircraft with good basic skills and instrument scan. Makes the job look easy.
M-19	PNF-1	2	Good scan, makes the job look easy.
NM-02	PNF-1	2	Good instrument cross check allowed him to be ahead of the aircraft.
NM-05	PNF-1	2	Average during training maneuvers.
NM-11	PNF-1	2	Good instrument scan & trimming allows PF to make things look easy.
NM-13	PNF-1	2	Good basic skills & scan make job look easier.
NM-14	PNF-1	2	Seems not to have to work to [sic] hard, particularly on approaches. Seems to be ahead of the aircraft due to good basic skills & instrument scan.
NM-16	PNF-2	2	See previous comments
NM-17	PNF-1	2	Scan is a little slow at times so PF has to work a bit harder to catch up.
NM-18	PNF-1	2	PF is ahead of aircraft - good instrument scan.
NM-19	PNF-1	2	PF ahead of the aircraft, makes the job seem easy.
NM-21	PNF-2	2	PF is simul instructor.
M-03	PNF-1	3	Higher physical workload due to being behind the airplane.

[23] Note that pilot NM-09 was excluded from all analyses because it was discovered only after his participation that he was not currently qualified on the B747-400 airplane. He was replaced by NM-21.

PF	PNF	Questionnaire	Comment
M-06	PNF-1	3	Work load on the first circuit was higher. Second was average, learned from first attempt.
M-07	PNF-1	3	same as average except on Vr cut - Late rudder application created more work
M-08	PNF-1	3	Slower than average instrument scan causes increased workload.
M-10	PNF-1	3	A little rough at times.
M-11	PNF-1	3	On approaches seems to make them look a bit easier than average due to good scan.
M-16	PNF-1	3	This is improving but still using large pitch inputs on short final.
M-17	PNF-1	3	Pilot has good, basic skills is ahead of the airplane making job look easy.
M-19	PNF-1	3	Above average skills, makes job look easy.
NM-02	PNF-1	3	Still the pilot has a good instrument cross check which puts him ahead of the aircraft & seems to be less workload.
NM-05	PNF-1	3	Good instrument cross check allows pilot to be ahead of the airplane. This makes for less apparent work load.
NM-08	PNF-1	3	Pilot seems ahead of the simulator, probably better than average instrument scan.
NM-11	PNF-1	3	Good basic skills allow PF to make operation look easy in all phases.
NM-13	PNF-1	3	Good basic skills - Job appears to be done with less work. Pilot well "ahead" of the aircraft.
NM-14	PNF-1	3	PF seems to be oscillating in roll control. In part this seemed to be due to not using rudder trim on first approach. On second approach used rudder trim but oscillation did not go away fully, but improved.
NM-17	PNF-1	3	Scan is slow. Speed control on approaches is lacking. Overall, PF is behind the aircraft & working hard to catch up.
NM-18	PNF-1	3	PF ahead of the aircraft due to a good instrument scan.
NM-19	PNF-1	3	Lower than average workload on the whole except for the first take off (VR Cut).
M-03	PNF-1	4	At times higher workload as pilot overcorrected and got behind the aircraft.
M-06	PNF-1	4	About average but worked rudder a bit more than normal, particularly in turns.
M-07	PNF-1	4	Approach work load a bit better than average.
M-08	PNF-1	4	Instrument scan improved sufficiently to be about average.
M-10	PNF-1	4	Was a bit rough at times, but average.
M-11	PNF-1	4	A little higher workload on takeoffs & lower on approaches.
M-12	PNF-2	4	see previous comment [PF I think was somewhat tired due to more raw data flying than normal.]
M-14	PNF-2	4	PF maybe tired (jet lag).
M-15	PNF-1	4	Good basic skills/ instrument helps PF stay ahead.
M-17	PNF-1	4	As before, the job looked easy due to good basic skills.
M-19	PNF-1	4	PF was ahead of the aircraft making the job look easy.
NM-02	PNF-1	4	Lower due better than average level of proficiency.
NM-05	PNF-1	4	Pilot didn't seem to have to work as hard as average to achieve improvement on approaches. About average though on engine cuts.
NM-08	PNF-1	4	Good scan keeps him ahead of simulator and makes flying look easy.
NM-11	PNF-1	4	As before, good basic skills allow PF to make the job look easy.
NM-13	PNF-1	4	Did not appear to work as hard as some, good basic skills generally out "ahead" of the airplane.
NM-14	PNF-1	4	Now seems to be lower workload - PF seems to have better "feel" of aircraft in roll.
NM-17	PNF-1	4	Slower than average instrument scan makes work for PF.
NM-18	PNF-1	4	Good basic skills and instrument scan - makes it look easy.

PF	PNF	Questionnaire	Comment
NM-19	PNF-1	4	PF's good scan helped him stay ahead of the sim. Makes for lighter workload.
NM-21	PNF-2	4	See previous. [PF hurried flt and tended to overcontrol. Jerky flight controls to do so.]

APPENDIX 33. PNF COMMENTS ON PF'S GAINING PROFICIENCY[24]

PF	PNF	Questionnaire	Maneuver	Comment
M-03	PNF-1	2	engine-out sidestep landing	Very experienced. Above [ratings] is based on that.
M-06	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Seems to have better than average instrument cross check.
M-07	PNF-1	2	engine cut at VR; overall gain of proficiency	Wrong rudder on 2nd VR Cut. Overall gain average harder on average based on VR cuts
M-08	PNF-1	2	engine cut at V1	Gained proficiency as average except V1 cut which was much better improvement.
M-09	PNF-2	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Gained proficiency slightly easier, scan pattern increased.
M-10	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Big improvement over first attempt. Seems to have good instrument scan.
M-11	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing	Seems to have a bit more problem with rudder control on engine failures on take off. Instrumt [sic] scan on approaches is better than average. Above average approaches & landings.
M-12	PNF-2	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	P.F. began to get tired during last half of session.

[24] Note that pilot NM-09 was excluded from all analyses because it was discovered only after his participation that he was not currently qualified on the B747-400 airplane. He was replaced by NM-21.

PF	PNF	Questionnaire	Maneuver	Comment
M-13	PNF-2	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF has good x [cross] scan.
M-14	PNF-2	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF has good understanding of flight director use. I think PF became tired during final sequence & slightly overcontrol loc intercept, but a good job.
M-15	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good basic flying ability (instrument scan) allowed for above average improvement.
M-16	PNF-1	2	engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Has trouble with raw data approaches. Did not seem to be aware of wind direction/ velocity read-out on ND.
M-17	PNF-1	2	engine cut at V1; engine cut at VR; engine-out sidestep landing; overall gain of proficiency	Good scan and basic skills. One straight-in approach did not go too well but others were good.
M-19	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF started with good basic skills & scan to build on.
NM-02	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Has good cross check, particularly for getting as little flying as he does.
NM-05	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Average for experienced pilot.

PF	PNF	Questionnaire	Maneuver	Comment
NM-06	PNF-2	2	engine cut at VR; engine-out straight-in approach/landing; overall gain of proficiency	PF slow to increase scan pattern, therefore overcorrected & chased information.
NM-08	PNF-1	2	engine-out straight-in approach/landing; engine-out sidestep landing	Approach speeds are high without correction.
NM-10	PNF-2	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF is a current sim instructor.
NM-11	PNF-1	2	engine cut at V1; engine cut at VR	Gain in proficiency on engine cuts came as much from explaining/understanding F/D & what it commands for speed as flight practice. Good improvement in heading control with practice.(engine cuts)
NM-13	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good instrument scan & good basic skills.
NM-14	PNF-1	2	engine cut at V1; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good overall gain in proficiency. Crashed on 1st V1 cut. But got to average level after that. All approaches became above average, except last straight in approach.
NM-15	PNF-2	2	engine-out straight-in approach/landing	On ILS P.F. slightly slow on wind change on appch.
NM-16	PNF-2	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF has good scan pattern.
NM-17	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	On one VR cut simulator seemed to turn left for no apparent reason, before engine failure, sim was frozen, all others normal.

PF	PNF	Questionnaire	Maneuver	Comment
NM-18	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good basic flying skills and instrument scas [sic].
NM-19	PNF-1	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good scan and skills to start with, allowed good gain in prof. particularly with engine failures.
NM-21	PNF-2	2	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF is an instructor in simul.
M-03	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; overall gain of proficiency	Coming back after lunch seems to be hard. Seems to take time to get back up to speed.
M-06	PNF-1	3	engine cut at VR; engine-out straight-in approach/landing	In first engine cut and approach (VR & straight in) gain in proficiency was a bit below normal. Second circuit was average.
M-07	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Take offs about the same as start - (Approaches/Landings better) Used correct rudder inputs but a bit late.
M-08	PNF-1	3	engine cut at V1	Regressed on Engine Failure at V1.
M-10	PNF-1	3	engine cut at V1; engine cut at VR;	First after lunch, heading control on take offs with engine failures not as good as practice session - approaches were average
M-11	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good improvement in engine cuts. Continues to improve approaches.
M-12	PNF-2	3	engine-out straight-in approach/landing	PF slightly over controlled pitch on raw data ILS (after lunch).

PF	PNF	Questionnaire	Maneuver	Comment
M-14	PNF-2	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF seems to be a little tired, possible jet lag.
M-15	PNF-1	3	engine cut at VR	Engine cut at VR seemed to be a bit of a surprise.
M-16	PNF-1	3	engine-out straight-in approach/landing; overall gain of proficiency	Straight in approach is getting better but would still be a go around under normal conditions.
M-17	PNF-1	3	engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good inst. scan & basic abilities.
M-18	PNF-2	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF had slight lunch break letdown.
M-19	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF started with above average skills.
M-20	PNF-2	3	engine-out straight-in approach/landing	PF had slight let down on ILS approach (lunch).
NM-02	PNF-1	3	engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Above average skill in the begining [sic].
NM-05	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Has good cross check & is a bit further ahead of the aircraft than average.
NM-06	PNF-2	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Proficiency increaced [sic] at a normal rate from proficiency during training phase.

PF	PNF	Questionnaire	Maneuver	Comment
NM-08	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good overall improvement.
NM-11	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Has gained proficiency easier than average - better than average basic skills.
NM-13	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Improvement after the break better than average. Good basic flying skills & scan.
NM-14	PNF-1	3	engine-out straight-in approach/landing; engine-out sidestep landing	Engine failures acceptable, approaches good - PF seems to have good instrument scan.
NM-16	PNF-2	3	engine cut at VR	P.F. seem to over react to motion on VR cut. Improved quickly.
NM-17	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; overall gain of proficiency	Engine cut at V1 was better than VR cut. VR cut was almost crash. Not having motion washed out took PF by surprise. Speed on straight in approach was about 20 kts high--Side step approach was almost normal with speed about 10 kts high. Also on VR engine cut, believe PF initially applied wrong rudder
NM-18	PNF-1	3	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good basic flying skills & scan.
NM-19	PNF-1	3	engine cut at V1; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	VR cut was first take off - after that, PF got the "feel" of simulator somewhat better.
M-03	PNF-1	4	engine cut at VR; engine-out straight-in approach/landing; overall gain of proficiency	Seemed to do better in the morning.

PF	PNF	Questionnaire	Maneuver	Comment
M-06	PNF-1	4	engine cut at VR	Engine cut at Vr made harder by use of wrong rudder at engine failure. After recovery, average performance.
M-07	PNF-1	4	engine-out straight-in approach/landing; engine-out sidestep landing	Takeoffs average this time. Approaches above average.
M-09	PNF-2	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	P.F. has good scan & flying background.
M-11	PNF-1	4	engine-out straight-in approach/landing; engine-out sidestep landing	V1/ VR Cuts improved as average. Approaches improved better than average due good instrument scan.
M-12	PNF-2	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF I think was somewhat tired due to more raw data flying than normal.
M-13	PNF-2	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF may have become a little bored or tired during last two sessions.
M-14	PNF-2	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF I think was tired. (jet lag?)
M-18	PNF-2	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	PF flew this session without using rudder trim therefore tended to slightly overcontrol.
M-19	PNF-1	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Above average skills starting.

PF	PNF	Questionnaire	Maneuver	Comment
NM-02	PNF-1	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Pilot started from good level of proficiency. Gained proficiency as instrument flying basics were already good.
NM-05	PNF-1	4	engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	As before, good basic instrument cross-check makes improvement easier.
NM-08	PNF-1	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good gain in proficiency. Good basic flying ability - good scan.
NM-11	PNF-1	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good basic flying skills allowing better than average progress.
NM-13	PNF-1	4	engine cut at V1; engine cut at VR; engine-out sidestep landing; overall gain of proficiency	Good basic skills, & instrument scan. Backslid a little on straight in approach as speed got a little low.
NM-14	PNF-1	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Oscilation [sic] in roll much improved from previous. Seems to have good basic skills & be ahead of the aircraft.
NM-15	PNF-2	4	engine cut at V1; engine cut at VR	P.F. tends to allow a/c to drift off LOC/G.S. after visual contact with-out FLT DIR.
NM-16	PNF-2	4	engine cut at VR	P.F. still over controls on VR cut.
NM-17	PNF-1	4	engine-out sidestep landing	Speed control on straight-in landing was about the only problem this time.
NM-18	PNF-1	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good basic skills better than average instrument scan.

PF	PNF	Questionnaire	Maneuver	Comment
NM-19	PNF-1	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	Good scan and skills to start with.
NM-20	PNF-2	4	engine-out straight-in approach/landing;	PF overcontrol with full motion
NM-21	PNF-2	4	engine cut at V1; engine cut at VR; engine-out straight-in approach/landing; engine-out sidestep landing; overall gain of proficiency	P.F. is siml [simulator] instru [instructor]. teh