NASA Technical Memorandum 104776

Analysis of Differences Between Seating Positions in Simulators and Orbiters

Philip T. Mongan
Lyndon B. Johnson Space Center
Houston, Texas

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
1993

Acknowledgments

This testing was conducted at the Johnson Space Center in the FFT, CCT, and SMS Motion Base and Fixed Base trainers, and also at the Kennedy Space Center on OV-103. The test team consisted of Ken Trujillo and Roy Weeks, who assisted in the definition of the measurements to be taken and took the measurements, and Sudhakar Rajulu, who took all of the anthropometry measurements. I would also like to thank Al Rochford, Troy Stewart, Jean Alexander, and John Hopkins for providing suit support and consulting support on the crew equipment.

Contents

Acronyms

CCT	Crew Compartment Trainer
CDR	Commander
FFT	Full Fuselage Trainer
LPU	life preserver unit
PLT	Pilot
SMS	Shuttle Mission Simulator
TCDT	terminal countdown test demonstration

Introduction

There have been numerous crew comments indicating that Space Shuttle simulator seats place the crew members in a position different from that of the actual Orbiter seats. These comments have come mostly from the commander (CDR) and pilot (PLT), but the position difference has also been noticed by some mission specialists. Consequently, the crew feel that they launch in a different position, and with a different reach and visibility, from that in which they trained. Additionally, there has been one comment that on the launch pad the flight deck crew felt as if they were in a heads-down attitude.

To understand what is causing the differences between the training and flight eye positions, the following three areas were studied.

- Key dimensions, which were considered important to spatial orientation, were compared between the Orbiters and simulators. These were dimensions such as seat back to glareshield and seat pan to overhead. Measurements were taken on the Crew Compartment Trainer (CCT), Full Fuselage Trainer (FFT), the Shuttle Mission Simulator (SMS)-Motion Base, and the SMS-Fixed Base, and OV-103 (Discovery).

- The differences between flight and training crew equipment, and how these differences may contribute to the problem, were discussed with the engineers and technicians who are responsible for the associated equipment.

- Eye position measurements were taken on subjects to assess any differences which could be attributed to the different methods of ingressing the Orbiters and the simulators. These measurements were taken with a standard anthropometer on six astronauts who participated as the test subjects. The technicians who are actually responsible for assisting the astronauts with suit donning and Orbiter and simulator ingress performed their respective duties for this test. The CCT was used to simulate Orbiter ingress and associated eye position measurements because it can be turned vertical and provide a good representation of an actual Orbiter ingress, and the SMS-Motion Base was used for the simulator measurements.

This report contains the data found relating to these three areas, the analysis of the data, and the recommendations.

Relevant Data

Dimensions

Several measurements important to spatial orientation were taken and compared in the trainers, simulators, and OV-103. Although measurements were not taken on the other Orbiters for this study, the expected differences have been identified based on some limited measurements taken on OV-102 and OV-104 in 1988. The data in table 1 are key dimensional differences between OV-103 and the listed trainers and simulators, which would affect the position of the crewmembers with respect to certain panels.

It should also be noted that there is a difference between the overhead talkbacks in the Orbiters and the SMS; the overhead talkbacks are more recessed in the Orbiter.

In addition to the standard measurements, the vertical angle of OV-104 was also checked on the pad as it was being processed to support STS-45. This angle was compared to the SMS-Motion Base and the CCT launch training positions. Table 2 gives the angles measured on the flight deck floor at the seat 4 position relative to the ground.

Table 1. Trainer and Simulator Deltas with Respect to OV-103

Location Measured	*Differences between OV-103 and the Trainers and Simulators			
	SMS-Motion Base (in.)	SMS-Fixed Base	CCT (in.)	FFT (in.)
CDR Seat Pan to Overhead	-0.1	-0.1	0.1	0.0
PLT Seat Pan to Overhead	-0.4	-0.1	-0.1	n/a
CDR Seat Back to Glareshield	0.6	0.0	0.1	0.6
PLT Seat Back to Glareshield	0.3	0.5	0.5	n/a
CDR Seat Back to Instrument Panel	-0.1	-0.3	-0.2	0.3
PLT Seat Back to Instrument Panel	0.0	0.2	-0.1	n/a
CDR Seat Back to Eyebrow Panel	0.1	-0.3	-0.6	n/a
PLT Seat Back to Eyebrow Panel	0.3	0.1	-0.3	n/a
Seat 4 Forward Studs to Center Console	0.3	-0.4	0.1	0.1
Seat 4 Floor to Ceiling	n/a	-0.1	0.0	-0.2

*Negative numbers indicate that the distance is less in the trainer than in OV-103. Error for these dimensions is .2 in.

Table 2. Flight Deck Floor Angles - Launch Position

Vehicle	Flight Deck Floor Angle
OV-104	90°
SMS-Motion Base	73°
CCT	89.5°

Crew Equipment

To understand how the differences between flight and training equipment affect eye position, interviews were conducted with the suit technicians regarding the fidelity of the training hardware. The results with respect to crew equipment are outlined below.

- External headrest pads - The external headrest pads are crew dependent and vary from 0.5 to 4 in. These can be changed at any time and often at terminal countdown test demonstration (TCDT) the crew will request to increase the thickness of their pads by adding a removable one (i.e., going from a 3 in. pad prior to TCDT, to a 3 in. and a 1 in. pad during TCDT).

- Internal helmet pads - The internal helmet pads are crew dependent and vary from .25 to 1.5 in. The initial fit checks are done at Boeing, and most of the changes are worked out at the Johnson Space Center, but occasionally someone may want to change the thickness at TCDT.

- Seat cushions and head pads - The suited runs in the SMS use identical seat cushions and head pads as the Orbiters.

- Spacer cushions - The nonsuited runs in the SMS use spacer cushions and probably do not position the eye level in the same location as the suited runs.

- Seats - The seats in the SMS, CCT, and Orbiters are the same configuration.

- Parachutes - The training and flight parachutes are identical in design and packing. The only differences expected are that the training parachutes will be less stiff and possibly a little thinner (more compressed) because they are used so often.

- Suit - The actual flight suits are used for training. These are fit to the crewmember and adjusted as necessary during the training flow. By the time the crew gets to TCDT all the adjustments have generally been completed.

- Survival gear - Training is conducted with the full complement of survival gear. The equipment is identical except for the life preserver units (LPUs). The training LPUs are foam pads and do not go across the back. The flight LPUs have a rubber bladder which goes across the back. This bladder is deflated, however, and should contribute very little to raising the crewmember off of the seat.

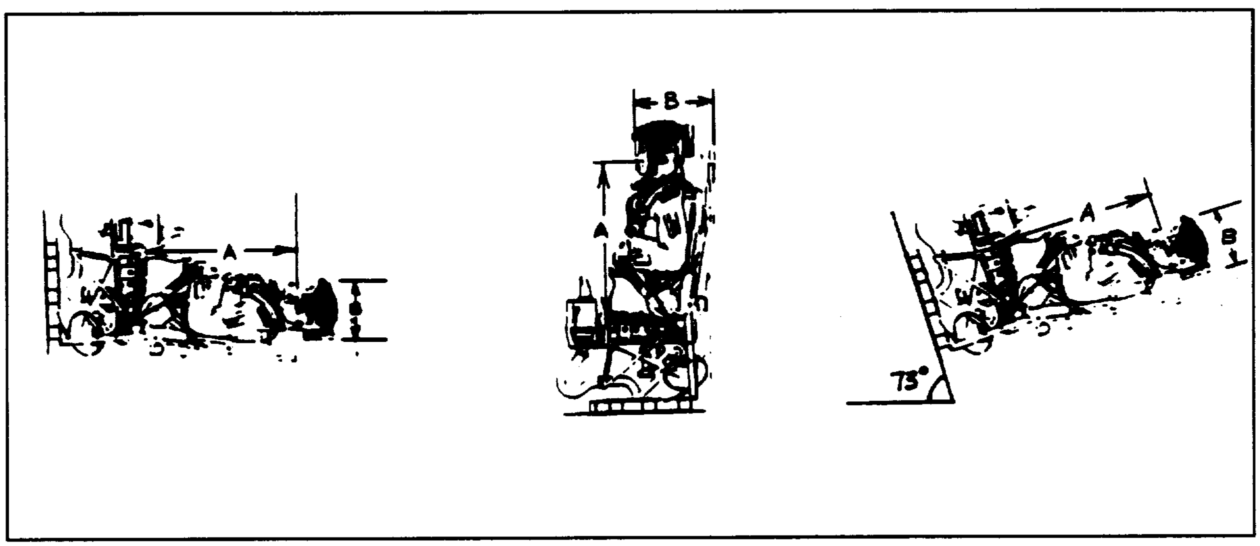
- Lumbar pads - The crew has the option of choosing the full lumbar pad or the regular lumbar pad. The full lumbar pad props the crewmember up higher off the seat backrest. Sometimes a crewmember will choose a regular lumbar pad and then change to a full lumbar pad.

- Suit inflation - Typically the suit will be uninflated for normal operations. The suit has been partially inflated on the launch pad by some crewmembers to try to eliminate some discomfort associated with the suit.

Methods of Ingress

The methods of ingress for the SMS and Orbiters were evaluated to determine their effects on the eye position. On the launch pad the crews ingress the Orbiter seats on their backs and use the lap belts to cinch themselves into the seat pan. In the SMS, however, the crews ingress horizontally and get strapped into the seat, and then the SMS rotates to the 73° launch position. To understand the difference in eye position attributed to these different modes of ingress, measurements were conducted in the CCT and compared to those taken in the SMS.

The CCT was used to establish the crewmembers' eye position with respect to ingressing a vertical Orbiter. These measurements were taken on suited crewmembers after they were strapped into a vertical CCT by the suit technicians. Then the same measurements were taken on the same crewmembers in the SMS-Motion Base. The crewmembers were strapped into the horizontal Motion Base and then rotated to the 73° launch position (per normal SMS procedures). Figure 1 shows the two measurements which were taken during these tests.



Orbiter at Ingress | SMS at Ingress | SMS at Launch

Figure 1. Measurements Taken at Ingress and Launch.
(A = Eye from Seat Pan; B = Eye from Headrest)

Table 3 shows the differences recorded between the CCT and SMS measurements using the CCT as a reference. After measurements were taken at the 73° position the SMS-Motion Base was driven to the 90° position and the same measurements were retaken.

Table 3. SMS Deltas with Respect to CCT

Test Subject	Differences between the vertical CCT and the SMS at the 73° position for the following measurements*	
	Eye from Seat Pan (in.)	Eye from Headrest (in.)
1	-1.3	1.0
2	-1.7	2.2
3	-2.9	0.5
4	-1.1	0.8
5	-3.5	0.4
6	-1.1	0.1

*Negative numbers indicate that the distance was less in the SMS than in the CCT.

Analysis of the Data

The dimensional deltas indicate that most of the dimensional differences between the trainers, simulators, and Orbiters are within 0.25 in., with some differences around 0.5 in. Additionally, the 1988 data, which were taken prior to the CDR and PLT seat relocation, indicate that OV-102 and OV-104 are within this range. These differences alone are probably not of the magnitude to account for the crew comments. When combined with the other variables, though, they could be a contributor to the noted problem.

The training crew equipment is virtually identical to the flight equipment. There should be no changes in the eye position attributed to differences in flight and training equipment unless different headrest pads or internal helmet pads are chosen at TCDT or launch. The training parachute is slightly more compressed than the flight parachute, because of extensive use, which would make some difference in reach toward the forward direction. Again, this alone would not account for the perceived differences which have been encountered between the trainers, simulators, and Orbiters.

The differences in eye position attributed to the different methods of ingress for the Orbiters and the SMS are significant. The seated eye height is greater in the Orbiters at launch by a range of 1 to 3.5 in. This is not surprising when considering that friction between the crewmember and the seat, and also spinal stretch, are factors when ingressing on the launch pad. In the SMS, however, gravity will compress the spine and there is no friction between the crewmember and parachute to overcome when being seated. This causes the crewmember to be more firmly planted in the seat pan and, therefore, shorter. When the crewmember is rotated to the 73° launch position some stretch occurs, but it is not enough to position the eye where it would be on the launch pad. This condition would give the crewmember the feeling of being seated further down in the SMS than the Orbiter. Additionally, more stretch occurs as the SMS is rotated from 73° to 90°, but the eye position still falls short of what it would be from a pad ingress.

The difference in eye position relative to the headrest is also as expected. The eye is further from the headrest in the SMS at the 73° position than it is in the Orbiter by a range from 0.1 to 2.2 in. This condition can be attributed to head pad compression being greater at 90° than at 73° because of gravity, thereby causing the crewmember to feel closer to the forward panels in the SMS than in the Orbiter. As the SMS was rotated to 90°, the head pads compressed more and the eye position was very close to what was measured for the launch pad configuration.

Conclusions

Three areas were analyzed to address the reported problem of simulator seats placing the crew in a different position than the Orbiter seats: the flight and training crew equipment, dimensional differences between the Orbiters and simulators, and differences in eye position with respect to ingressing simulators vs. ingressing Orbiters.

A comparison of the flight and training crew equipment indicates that they are virtually identical. Although there are some small differences, nothing should cause a displacement of the crewmember of the magnitude which has been reported.

There are dimensional differences between the flight vehicles and trainers. The measurements taken were those which are important to spatial orientation such as seat pan to overhead panel, seat back to glareshield, etc. Most of the differences between the Orbiters and trainers were within 0.25 in.; however, a few were around 0.5 in. Additionally, it should be noted that the overhead talkbacks in the Orbiters are more difficult to see because they are more recessed than the ones in the simulators. These dimensional differences, along with the recessed talkbacks, could be a contributor to the problem; however, they are not of the magnitude to be the sole contributor to the perceived difference between Orbiters and simulators.

The method of ingress appears to be the most significant contributor to the perceived difference between Orbiters and simulators. Since only six subjects were measured, no statistical significance can be attached to these numbers, but a consistent trend can be clearly seen. In the Orbiter the crewmembers ingress the seat in the vertical position. While ingressing they crawl in on their backs, having to overcome friction between their backs and the parachute (a Teflon cookie sheet assists), and stretching the spine as they try to cinch themselves into the seat pan with the lap belt. Ingressing the SMS-Motion Base is done in the horizontal position, however; then the simulator is rotated to 73° for the simulated launch. At ingress, gravity assists the crewmember into the seat pan and provides some spinal compression.

A clear trend can be seen that the distance from the eye to the seat pan in the SMS-Motion Base is shorter than the Orbiter in the launch position. Likewise, because the simulator launches at 73° and the Orbiter launches at 90°, the force of the head on the head pad because of gravity is greater in the Orbiter. This is consistent with the data which show the distance from the headrest to the eye as being greater in the simulator than the Orbiter.

Recommendations

From the preceding analysis it can be seen that the flight and training equipment are virtually identical, thus differences between the two are not a contributor to this problem. A caveat to this, though, is that a thicker external head pad may be beneficial in the Orbiter. The reasons for this are explained below in the discussion of the different methods of ingress.

Although there are some dimensional differences between the Orbiters and simulators, relocating the seats in either vehicle would be a significant task. Since there are dimensional differences not only between the simulators and Orbiters, but also between the various Orbiters, a very involved study would have to be undertaken to be sure that the problem is not made worse for any particular Orbiter. This is certainly not recommended, especially when most of the tolerances are within 0.25 in. and the costs of a modification like this would be high. It might be worthwhile to address the overhead talkbacks if the Astronaut Office feels that these are a significant problem.

The differences associated with the different methods of ingress can be addressed, however. Addressing these ingress modes should have the most significant impact on the problem at a reasonable cost. The seats in the SMS can be modified so that instead of going full down, they only go to within 1 to 3.5 in. from the bottom stop. The exact location of this seat stop position still needs to be decided; but, a reasonable guess, some trial and error with some pilot feedback is probably the best approach. An alternate approach would be to instruct simulator pilots to move their seats up a couple of inches from the bottom prior to launch. This may be more effective for pilots who have already flown, because they may be able to position the seat based on their recollection of the Orbiter seat position prior to launch.

Additionally, the headrests in the Orbiter could be thicker, by 0.1 to 2.2 in., to account for the difference in launch positions of 73° vs. 90°. This additional thickness could be determined real-time on the launch pad or at TCDT. This change, however, is not anticipated, because most crewmembers prefer the seat full aft for launch, and the seat could be moved forward to compensate for additional headpad thickness if desired.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
September 1993

3. REPORT TYPE AND DATES COVERED
Technical Memorandum

4. TITLE AND SUBTITLE
Analysis of Differences Between Seating Positions in Simulators and Orbiters

5. FUNDING NUMBERS

6. AUTHOR(S)
Philip T. Mongan

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Lyndon B. Johnson Space Center
Flight Crew Support Division
Houston, TX 77058

8. PERFORMING ORGANIZATION REPORT NUMBER
S-730

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, D.C. 20546-001

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
NASA-TM-104776

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Unclassified/Unlimited Publicly Available
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4600 Subject Category 54

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Crew comments indicate that Space Shuttle simulator seats place crewmembers in a position different from that of the actual Orbiter seats. The crew feel that they launch in a different position, and with a different reach and visibility, from that in which they had trained. This study examined three factors in differences between training and flight positions. (1) Key dimensions, which were considered important to spatial orientation, were compared in the Orbiters and simulators. These were dimensions such as seat back to glare shield and seat pan to overhead. (2) The differences between flight and training crew equipment, and how these differences may contribute to the problem, were discussed with engineers and technicians responsible for the equipment. (3) Eye position measurements were taken on subjects to assess any differences that could be attributed to different ingress methods in the Orbiters and the simulators. This report presents the data, analysis, and recommendations.

14. SUBJECT TERMS
Seats, Shuttle Mission Simulator, Simulators, Crews, Human Factors Engineering

15. NUMBER OF PAGES
9

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT
Unclassified

18. SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

19. SECURITY CLASSIFICATION OF ABSTRACT
Unclassified

20. LIMITATION OF ABSTRACT
UL