2.4 Evaluation of Life Sciences Glovebox (LSG) and Multi-Purpose Crew Restraint Concepts

FLIGHT DATES:
June 28-30, July 1, 2004

PRINCIPAL INVESTIGATOR:
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GOAL:
The goal of this investigation was the assessment of the adequacy of different restraint types for various onboard configurations.

OBJECTIVE:

The primary objective was to evaluate the usability of multiple crew restraints for use with the Life Sciences Glovebox (LSG) and for performing general purpose tasks. Since this flight was follow-on to the March 2004 flight evaluation, the primary objective included the testing of refined designs from the March flight, as well as some new design concepts for LSG and general purpose use. Secondary objectives included: (1) the evaluation of target sizes for a tablet computer, (2) usability of a speech-based procedure navigation tool, and (3) audio recording of typical voice commands for post-processing by a voice recognition system under development. These tasks were used as representative onboard tasks to be performed during evaluation of the general purpose restraints.

INTRODUCTION:

Within the scope of the "Multi-purpose Crew Restraints for Long Duration Spaceflights" project, funded by Code U, it was proposed to conduct a series of evaluations on the ground and on the KC-135 to investigate the human factors issues concerning confined/unique workstations, such as the design of crew restraints. The usability of multiple crew restraints was evaluated for use with the Life Sciences Glovebox (LSG) and for performing general purpose tasks. The purpose of the KC-135 microgravity evaluation was to: (1) to investigate the usability and effectiveness of the concepts developed, (2) to gather recommendations for further development of the concepts, and (3) to verify the validity of the existing requirements. Some designs had already been tested during a March KC-135 evaluation, and testing revealed the need for modifications/enhancements. This flight was designed to test the new iterations, as well as some new concepts. This flight also involved higher fidelity tasks in the LSG, and the addition of load cells on the gloveports.

METHODS AND MATERIALS:

<u>Test Conductors</u>

A group of 4 test conductors (evaluators) per day conducted the KC-135 usability evaluations, which occurred over 4 days. Each evaluator was certified to fly onboard the KC-135 by passing a Class III physical and completing the physiological training course. The evaluators were recruited from the NASA Johnson Space Center, and included two crewmembers.

<u>Apparatus</u>

KC-135 test articles, including the crew restraints, Life Sciences Glovebox (LSG) mock-up, and support hardware, were built per the KC-135 User's Guide. Four camcorders were flown to record video/audio data from the entire evaluation for postflight analysis. The following items were also used during the test:

- Laptop computers
- Tablet PC
- Audio tape recorder

In addition to restraint design changes, the fidelity of the LSG tasks was also increased. Actual LSG equipment (i.e., Data Input Device, Integrated Control Panel, OptiCells, syringes) was borrowed from the NASA Ames Research Center to use in the evaluation.

Restraints: Six restraint concepts were evaluated. One LSG restraint concept had multiple configurations to allow for adjustability and comfort. Components of the LSG restraint that were evaluated included: foot plates, thigh bar and lumbar support (see tripod structure in Figure 3). An additional LSG restraint concept [Texas A&M University (TAMU) Roller bar] had roller bars for the feet and waist. Three multi-purpose restraint concepts were also evaluated - an augmented handrail, padded socks, and toe loops. A bungee cord was also provided for the evaluators to use on the last flight day (per crewmember suggestion). On this day, participants used the foot plates and wrapped the bungee cord around their back and through the handle, routing the cord in front of them and attaching to the other handle (see bungee cord in Figure 3). While it was recognized that this violated one of the initial LSG requirements (no attachment to the LSG), the investigators thought it was worth testing the basic concept of an elastic "belt" support.

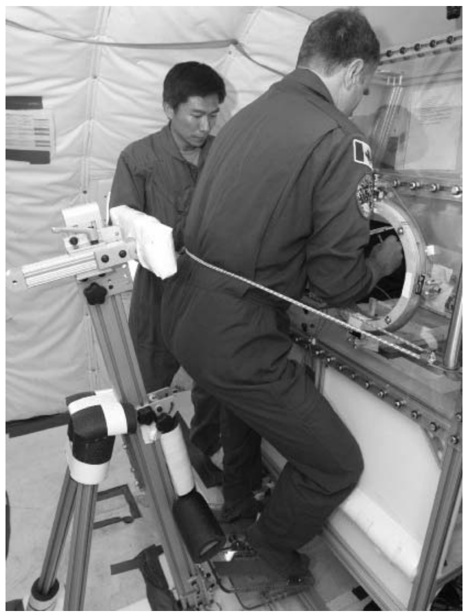

Figure 3. Evaluator using bungee cord and foot plates.

LSG Mock-up: The same mock-up used on the KC-135 flights in March was used during this evaluation, except that load cells were added to the gloveports for these flights. This was done in an attempt to quantify forces placed by crewmembers' arms on the gloveports while working in the LSG. These data will help determine how well a restraint supports the crewmember during glovebox tasks.

A scale-based questionnaire was developed for postflight administration. This questionnaire addressed the user interface issues and comfort of the crew restraint concepts.

Procedure

The restraints were evaluated in one of three different work areas on the workstation as shown in Figure 4: primary LSG (front), secondary LSG (side) and multi-purpose (back). A minimum of 30 parabolas per flight were dedicated for data collection. The remaining 10 parabolas were reserved for inadvertent disruptions such as turbulence or hardware problems. In-flight video (full body and close up views) of the tasks was recorded for postflight analysis. The questionnaire was administered post flight.

Tasks: The evaluators at the primary work area were performing simple representative glovebox tasks while in the LSG restraint. These tasks included: simulated filter change out by removing a foam core square from the back of the LSG work volume, and operations with the Data Input Device (DID), Internal Control Panel (ICP) and Opticells. The DID involved the use of a glide point computer input device; the ICP involved physical switch operations and the OptiCell injecting fluid into and from an OptiCell container.

The evaluators at the multi-purpose restraint site (back) were performing one of a number of technology evaluations while using a number of different restraints. These included evaluating pointing target sizes for a tablet computer, evaluating a speech-based procedure navigation tool, and making a voice recording.

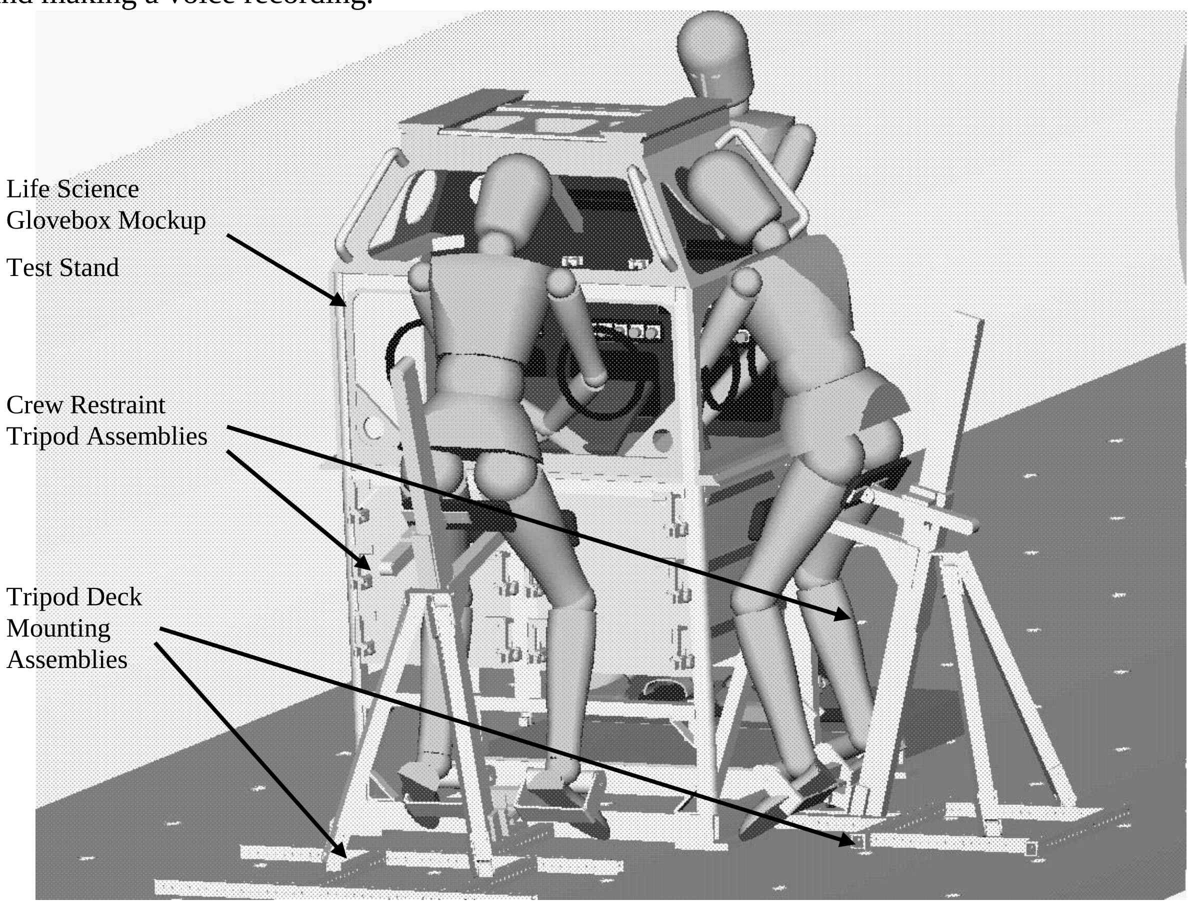

Figure 4: Test Configuration – View from Forward / Port Life Sciences Glovebox Test Stand

RESULTS:

Sixteen of the ratings gathered on the questionnaire were organized into two categories: Restraint Usability and Comfort. Ratings within each of the categories were very similar, and so were collapsed to produce two key metrics. Table 2 shows the two key metrics averaged over all participants.

Table 2. Ratings for Average Usability and Comfort.

Average Restraint Usability (ease of ingress/egress, stability, ease of performing operations, etc.)	**3.3**
Average Comfort Rating (comfort ratings for all parts of the body)	**3.5**

(1 = Needs Improvement, 5 = Excellent)

Summary of key comments from the evaluators:

- Restraint placed tall evaluators too high to perform glovebox operations comfortably.
- Thigh restraint hindered ability of shorter evaluators to reach to the back of the glovebox work volume.
- Thigh restraint prevented evaluators from floating into the LSG mockup.
- The foot plate strap should be wider and elastic.
- The bungee/foot plate combination worked well.
- The TAMU roller bar restraint had fabrication difficulties and did not function as intended

An in-depth analysis of the load cell data is currently in progress. Preliminary results indicate that whenever reaching is involved, there is an increase of force on the gloveports. This data will be beneficial to the LSG team in that it will provide some indication of the forces likely to be put on the glovebox when in use on ISS. An example graph of the load cell data is presented in Figure 5.

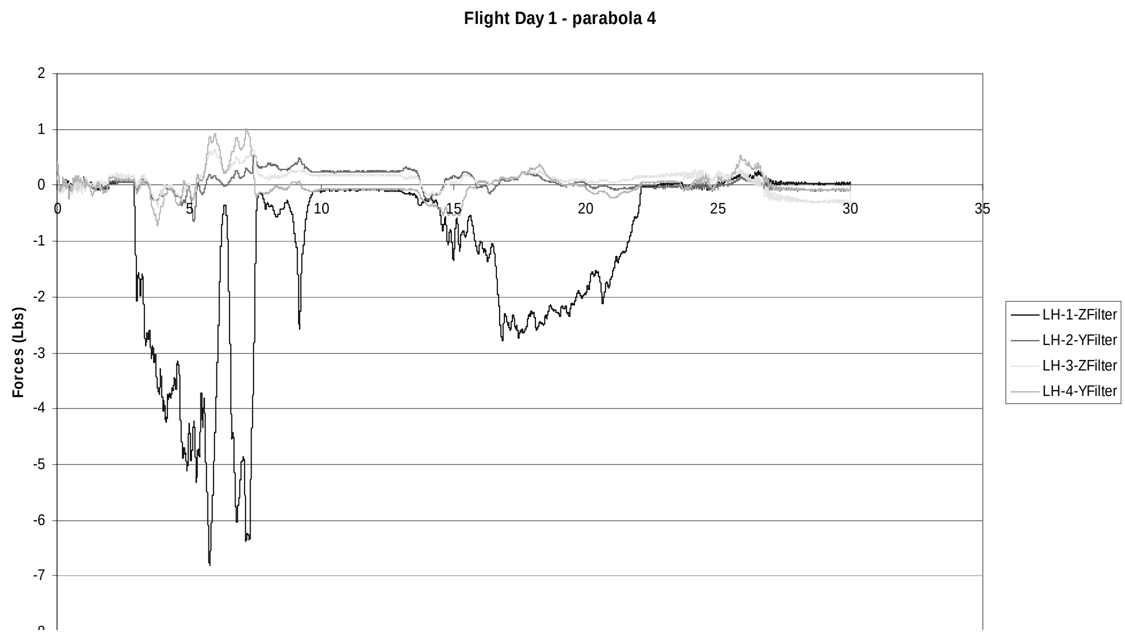

Figure 5. Graph of load cell data obtained from the left hand gloveport during parabola 4 on flight day 1.

The graph shows two periods of negative forces indicating times when contact was made with the left gloveport. The negative forces mean the load cell was in compression, so the evaluator during this parabola was pressing on the gloveport for stability.

Preliminary general purpose restraints results were as follows:

- The padded socks got mixed reviews. They were liked by some evaluators, but not others.
- The padded handrail performed well. Evaluators stated that it provided good stability and was very comfortable. It was also very easy to ingress and egress.
- The foot loops performed well.

Secondary Objectives

Target Size

Results showed that the smallest size targets (12 x 12 pixels) produced unacceptably high error rates. Further analyses are underway, and the data are being compared to ground-based pointing data before final conclusions are drawn.

Speech-based Procedure Navigation Tool

- It was difficult to hear the computer voice.
- Computer did not respond to some voice commands.
- Evaluators had to repeat themselves to get computer to respond.

The data and recordings were turned over to the principal investigators who developed the system.

Audio Recording of Voice Commands

- The recordings were turned over to the principal investigator who is developing the system.

CONCLUSIONS:

One of the problems seen to a greater degree in this evaluation was that very tall participants were unable to adequately adjust the restraint height (This flight had generally taller flyers). They had to crouch in order to place their hands/arms inside the glove ports. While the height of the footplates was adjustable, the limited height of the KC-135 cabin prevented adjustment beyond a certain point. The thigh restraint worked well for some and not as well for others; thus it was advantageous that it was optional (could be folded down). One of the comments captured on the questionnaire stated that the more experience you have in microgravity, the less restraint is required. The evaluators stated that the combination of the bungee cord and foot plates allowed for better access to areas within the LSG work volume. The bungee cord was stated to be very comfortable and provided the best posture for the evaluators. The implications of these comments need to be studied further, since attachment to the LSG is currently considered undesirable. However, the design concept of a flexible/elastic back support should be investigated further.

The padded handrail solution was probably the best of all the general purpose restraint concepts. It is a simple design that utilizes a hardware component already onboard ISS (handrail). It just involves the addition of padding. The rigid bar also appeared to result in less toe flexing than the foot loops, and therefore, probably longer term comfort.

PHOTOGRAPHS:

JSC2004E27355 to JSC2004E27357
JSC2004E27360
JSC2004E27384 to JSC2004E27385
JSC2004E27392 to JSC2004E27393
JSC2004E27395
JSC2004E28086
JSC2004E28093 to JSC2004E28095
JSC2004E28097
JSC2004E28104 to JSC2004E28105
JSC2004E28107
JSC2004E28113
JSC2004E28116
JSC2004E28121 to JSC2004E28127
JSC2004E28658 to JSC2004E28665
JSC2004E28278
JSC2004E28294 to JSC2004E28297
JSC2004E28406 to JSC2004E28415
JSC2004E28424 to JSC2004E28434
JSC2004E28446
JSC2004E28443 to JSC2004E28444

VIDEO:

- Zero-g June 29 – July 2, 2004, Reference Master: 718394

Videos available from Imagery and Publications Office (GS4), NASA/JSC.

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