TITLE:
Ergonomic Evaluation of the Foot Restraint Equipment Device (FRED)

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NASA Photo: 98EO6189

GOAL/OBJECTIVE:

The purpose of this evaluation was to identify user interface issues of the Foot Restraint Equipment Device (FRED) and crew restraint requirements for the Remote Manipulator System (RMS) workstation.

INTRODUCTION:

Within the scope of the Microgravity Workstation and Restraint Evaluation project, funded by the NASA Headquarters Life Sciences Division, evaluations were proposed to be conducted in ground, KC-135, and/or Shuttle environments to investigate the human factors engineering (HFE) issues concerning confined/unique workstations, including crew restraint requirements. As part of these evaluations, KC-135 flights were conducted to investigate user/ workstation/ restraint integration for microgravity use of the FRED with the RMS workstation. This evaluation was a pre-cursor to Detailed Supplementary Objective (DSO) - 904 on STS-88. On that mission, a small-statured astronaut will be using the FRED restraint while working at the Aft RMS workstation. The DSO will collect video for later posture analyses, as well as subjective data in the form of an electronic questionnaire.

This report describes the current FRED KC-135 evaluations. The primary objectives were to evaluate the usability of the FRED and to verify the DSO in-flight setup. The restraint interface evaluation consisted of four basic areas of restraint use: 1) adjustability; 2) general usability and comfort; 3) usability at the RMS workstation; and 4) assembly and disassembly.

METHODS AND MATERIALS:

A team of six test conductors evaluated the FRED prototype along with a mockup of the RMS workstation for two flights onboard the KC-135 in July of 1998. Four of the participants were experienced KC-135 flyers who have not previously been affected by motion sickness; two were first-time fliers. The evaluators represented a range of anthropometry from 5th percentile Japanese female to 95th percentile American male. The team evaluated viewing location and reach issues as well as crew restraint requirements and suggested changes and/or made other recommendations as appropriate.

This report is intended to document HFE findings based on in-flight observation and experience as well as subjective questionnaire data provided by five evaluators. Questionnaire items were rated on a scale of 1 - Completely Disagree to 7 - Completely Agree. Table 1 shows a complete list of FRED/RMS issues that were included in the questionnaire along with their average ratings. All of the participants ratings were on the same side of the scale (either agree or disagree) except where noted. The findings will be discussed in the following four sections.

RESULTS AND DISCUSSION:

Ingress/Egress and Adjustability:	AVERAGE RATING	Usability at the RMS Workstation:	AVERAGE RATING
Ingress performed easily	6.4	Reach to THC was acceptable	6.4
Egress performed easily	6.8	Reach to RHC was acceptable	6.4
Adjustability at the rack interface point (arm) was acceptable	5.2	Looking out Aft port window was acceptable	6.0
"Knee" joint location was acceptable	5.6	Looking at CCTV monitor was acceptable	7.0
"Knee" joint adjustability was acceptable	5.6	Reach to CCTV controls was acceptable	6.3
"Foot" joint location was acceptable	6.2	Reach to panel A8L was acceptabl	6.0
"Foot" joint adjustability was acceptable	5.4	Comfortable distance from the workstation was maintained	5.8
Height adjustability was acceptable	4.8	Angle relative to the workstation was acceptable	5.2
Adjustability while restrained was acceptable	3.3	Restraint able to provide optimal performance of the task	6.0
Adjustments were performed by one operator	5.5	Easy to find optimal restraint position	4.6
Adjustments were performed with one hand	1.4		
General Usability/Comfort:		**Assembly/Disassembly:**	
Able to support maximum reach	6.4	The leg bar was easily assembled to the rack interface bar	2.0
Allowed maintaining a stable posture	6.4	Knee pads and shaft were easily assembled to the silver bar	5.0
Provided a stable posture	5.4	Foot pads and shaft were easily assembled to the silver bar	5.0
Rack interface joint (mounting assembly) was stable	3.0	Disassembly was performed easily	5.8

Table 1. Questionnaire issues and average ratings. A rating of 7 = Completely Agree; 4 = Neutral; 1 = Completely Disagree.

Ingress/Egress and Adjustability

Both ingress and egress of the restraint were given acceptable ratings (average ratings of 6.4 and 6.8, respectively). Both the knee and foot joint locations and adjustability were also acceptable (average ratings of 5.6, 6.2, 5.6, and 5.4, respectively). In addition, the adjustability of the joint at the attachment mounting assembly was rated as acceptable (average rating of 5.2). The height adjustability was rated as marginally acceptable (average rating of 4.8). Participants agreed that adjustments can be performed by one operator

(average rating of 5.5), however, not while restrained (average rating of 3.3). The ability to adjust the restraint while ingressed has been replaced by discrete adjustment points, which provide more stability. Finally, participants disagreed that adjustments can be performed with only one hand (average rating of 1.4). Again, this was expected due to the discrete nature of the adjustment points -- participants were required to unscrew and remove the knee or foot pad shafts to adjust. However, it should be noted that operators will need an additional restraint (i.e. foot loops) to keep them stable while performing adjustments to the FRED.

General Usability and Comfort

Based on questionnaire responses, the restraint was able to support maximum reach (average rating of 6.4). All but one also agreed that the restraint provided a stable posture and allowed them to maintain this posture (average ratings of 6.4 and 5.4). One small-statured participant disagreed that the restraint was stable (rating of 3.0). However, this may have been due to the unstable KC-135 environment (i.e. negative-gravity periods). The joint on the attachment mounting assembly was rated as not stable (average rating of 3.0). Participants commented that the clutch/center hub slipped often. None of the participants reported experiencing any discomfort in their lower backs, thighs, calves, or feet. This result was expected due to the short periods of restraint use.

Usability at the RMS Workstation

A number of mockups of Aft RMS workstation components were provided for the two flights, including: Translational Hand Controller (THC), Rotational Hand Controller (RHC), CCTV monitors, and paper representations of the CCTV control panel, panel A8U, panel A8L, and the aft port window. Participants were tasked to reach or view these components. Reach to the THC and RHC were both rated as acceptable (average ratings of 6.4 for both). The ability to look at the CCTV monitors and to look out the aft port window were also rated as acceptable or completely acceptable (average ratings of 6.0 and 7.0, respectively). Finally, reach to the CCTV control panel and panel A8L were rated as acceptable (average ratings of 6.3 and 6.0, respectively).

Participants agreed that the FRED allowed them to maintain a comfortable distance from the workstation (average rating of 5.8), as well as a comfortable angle (average rating of 5.2). In addition, participants rated the restraint's ability to provide for optimal performance of the task as acceptable (average rating of 6.0). However, ratings were slightly lower for the ease of finding the optimal position (average rating of 4.6). One large-statured participant rated this as not easy (rating of 3.0). However, another participant commented that this would become easier with practice.

Assembly and Disassembly

Assembling the knee pads and foot pads to the leg bar were rated as acceptable (average ratings of 5.0 for both). However, four participants commented that the threads were

difficult to engage and that it took some effort to line the knobs up correctly so that the threads do not become stripped. Knobs with finger knurls to supply a better grip while tightening were recommended. The task of assembling the leg bar to the arm was rated as unacceptable (average rating of 2.0). Participants commented that it took quite a bit of effort to line up the holes and keep the two pieces stable and flush while connecting the short screw. Note that some of the difficulty in aligning pieces may have been a factor of the KC-135 environment (i.e., negative gravity periods). In addition, the orientation of the arm and leg bar pieces was not intuitive -- it was unclear to which side of the arm and in which direction the leg bar attaches.

Participants had no difficulty in disassembling the FRED (average rating of 5.8). However, participants commented that having Velcro on every piece would have been helpful for restraining items during assembly and disassembly. One participant commented that a one person assembly/disassembly would definitely require the use of a foot restraint.

CONCLUSIONS:

Recommendations for potential FRED modifications:

(1) Screws/knobs difficult to align and engage, sometimes became stripped.
RECOMMENDATION: The addition of a rubber piece at the entranceway to the screw holes would aid in screw/knob alignment and may help to prevent stripping and jamming.

(2) Difficulty in aligning leg bar with arm.
RECOMMENDATION: The addition of labels indicating which side of the arm the leg bar lies against would promote efficiency in assembly. Also, labels indicating which direction the angle adjustment should face (either into or away from the workstation) would be beneficial for efficient assembly, as well as, added stability. Another approach is to provide a sketch of the assembly as part of the procedure.

(2) Knobs difficult to tighten.
RECOMMENDATION: The addition of knurls to the FRED knobs will aid in gripping the knob and tightening.

(3) Difficult to contain FRED components while assembling/disassembling.
RECOMMENDATION: The addition of Velcro to the components will aid in assembly and disassembly of the FRED by one operator, since both hands are needed to perform the task.

While adjustability mechanisms and stability need some modifications, the design interface was acceptable overall, especially in terms of the RMS operator tasks. One participant commented, once properly adjusted the FRED was very comfortable and would clearly enhance RMS operations.

PHOTOGRAPHS:

98EO6160 to 98EO6172
98EO6181 to 98EO6182
98EO6188 to 98EO6189
98EO6193
98EO6211 to 98EO6221

VIDEO:

Zero-G week of July 21-23, 1998, PMU: 11/46611, Master: 615618

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