

Using Transom Jack in the Human Engineering Analysis of the Materials Science Research Rack-1 and Quench Module Insert

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ABSTRACT

This paper describes the human engineering analysis performed on the Materials Science Research Rack-1 and Quench Module Insert (MSRR-1/QMI) using Transom Jack (Jack) software. The Jack software was used to model a virtual environment consisting of the MSRR-1/QMI hardware configuration and human figures representing the 95th percentile male and 5th percentile female. The purpose of the simulation was to assess the human interfaces in the design for their ability to meet the requirements of the Pressurized Payloads Interface Requirements Document – International Space Program, Revision C (SSP 57000).

Jack was used in the evaluation because of its ability to correctly model anthropometric body measurements and the physical behavior of astronauts working in microgravity, which is referred to as the neutral body posture. The Jack model allows evaluation of crewmember interaction with hardware through task simulation including but not limited to collision avoidance behaviors, hand/eye coordination, reach path planning, and automatic grasping to part contours. Specifically, this virtual simulation depicts the human figures performing the QMI installation and check-out, sample cartridge insertion and removal, and gas bottle drawer removal. These tasks were evaluated in terms of adequate clearance in reach envelopes, adequate accessibility in work envelopes, appropriate line of sight in visual envelopes, and accommodation of full size range for male and female stature maneuverability.

The results of the human engineering analysis virtual simulation indicate that most of the associated requirements of SSP 57000 were met. However, some hardware design considerations and crew procedures modifications are recommended to improve accessibility, provide an adequate work envelope, reduce awkward body posture, and eliminate permanent protrusions.

Introduction

This paper describes the human engineering analysis performed on the Materials Science Research Rack-1 and Quench Module Insert (MSRR-1/QMI) using Transom Jack (Jack) software. The Jack software was used to model a virtual environment consisting of the MSRR-1/QMI hardware configuration and human figures representing the 95th percentile male and 5th percentile female. The

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The next section gives the purpose of the human engineering analysis beginning with a description of the MSRR-1/QMI. Following the statement of the purpose are the details of the method of analysis. The human engineering requirements, operations scenarios, and apparatus are detailed. The final section discusses the results of the analysis and the associated future work.

Purpose

Human engineering requirements for all approved hardware are documented in the Pressurized Payloads Interface Requirements Document – International Space Program, Revision C (SSP 57000), which details the standards and specifications to be met by engineering designs. The SSP 57000 Revision C was revised to in July 1999. However, because this analysis was finished before the revision, we shall continue referring to version C for this work.

The Materials Science Research Facility (MSRF) project team charged The Human Engineering Analysis Team with the task of verifying that all human engineering requirements are met. Those requirements related to reach, work, and visual envelopes impact to the design of MSRR-1/QMI. The verification process is part of the total quality and reliability cycle that assures NASA's commitment to (1) ensure that all hardware interfaces have the highest usability and (2) warrant that the compatibility of the interfaces between subsystems will be suitable for the crew members' duties.

Description of MSRR-1/QMI

In order to understand this human engineering task, we must explain the full scope of the project. The First Materials Science Research Rack (MSRR-1) is the first component of the MSRF. The MSRF is a multi-rack facility that houses independent MSRR's aboard the International Space Station (ISS). The MSRR-1 is a payload collaboration of two separate agencies, the European Space Agency (ESA) and NASA. The scientific data provided by the MSRR-1 will be the result of several studies of the different behaviors of various materials exposed to high temperature processing while suspended in a vacuumed low-gravity environment. [1]

The MSRR-1 contains two furnaces and other supporting subsystems. [1] This work described in this paper relates to the Quench Module Insert (QMI) subsystem. Housed in the MSRR-1's experiment module, the QMI facilitates the scientific investigations of solidifying alloys, metals, and composite materials. The QMI is a quenching or cooling system that provides a rush of liquid over the

Sample Cartridge Assembly (SACA) after the furnace has heated the materials enclosed in the SACA. The resulting property changes of the sample materials are collected as data and stored for future use. [2]

Crewmembers will interface with the QMI and SACA in various operations scenarios. Three such scenarios were modeled for this work: QMI installation and check-out, sample cartridge insertion and removal, and gas bottle drawer removal. (Refer to screen shot 1.) Each of these tasks will require that the crewmember remove and secure hardware and verify connections using the hands and special tools. (Refer to screen shot 2.) Consequently, it is necessary to verify that the subsystem design supports the following:

1. Sufficient space for various body types or full size range accommodation without hindrance or interference from protrusions;
2. Adequate reach and work envelopes for manipulation of hardware and connectors and for tool use by either a left-handed or right-handed crewmember; and
3. Appropriate visibility of hardware and connections.

In the following section, the approach to analyzing whether or not these requirements are met by the design is explained.

Human Engineering Analysis Approach

The approach to performing the human engineering analysis was to model the MSRR-1/QMI hardware and crewmember interaction with the hardware using a virtual simulation. This section describes the tasks that were modeled for the analysis, the software used for the simulation, and the development of human models.

The virtual reality software used to do the analysis of the human interaction with the MSRR-1/QMI hardware is called Transom JACK (JACK). Created by students and faculty at the University of Pennsylvania and later purchased by Transom technologies, JACK currently is being marketed and developed by EAI Transom Technologies in Ann Arbor, Michigan. The software derives its name from the virtual human figure, JACK, which is used within the virtual environment. Early graphic depiction of the human shape within the software was basic, with very rudimentary figures. Today, the JACK software has developed into a powerful tool widely used in commercial industry and government agencies to assist human factors (HF) engineers in the design, manufacturing, and maintenance of developing products. JACK allows HF engineers to “develop products centered on humans and evaluate designs based on ergonomic concerns, account for different sizes and shapes of people in designs, and consider human factors in the design before building physical prototypes” by taking advantage of the capabilities of virtual reality (VR). [5]

In applying JACK to the human engineering analysis of the MSRR-1/QMI hardware, the software was run on a Silicon Graphics UNIX based workstation. The entire virtual environment, including the hardware subsystem configuration, special tools, and human models, was created using the basic CAD tools provided within the JACK software platform.

Analyzing humans in zero-gravity environments is the value JACK offers in the task analysis of the MSRR-1/QMI hardware. The virtual reality JACK figure accurately reflects human constraints and joint movement, and is scaleable to any anthropometric human size. For example, an actual crewmember's body measurements can be used to create a scale model human figure within the JACK virtual environment. Another value of using JACK for the analysis is the ability to see a crewmember's reach, fit, comfort and vision from within the environment. Collision avoidance, hand/eye coordination, reach path planning and automatic grasping to part contours can be simulated with human factors tools provided in the JACK software. [3] One such JACK feature used in the analysis of the MSRR-1/QMI task is the feature allowing a view from the human figure's eyes. This feature allowed the investigators to visually determine the accessibility of all bolt hardware. (*Refer to screen shot 3.*)

Of particular significance to the human engineering analysis was correct modeling of the neutral body posture (NBP), or the micro-gravity effects on the human body. In space, the absence of gravity causes the body's muscles to retract. As a result, the crewmember assumes a fetus-type posture. Generic NBP of male and female human figures were created in JACK. The initial step in creating a model of the NBP was to scan existing illustrations of humans at front, top, and side views in the NBP. These scanned images were then placed in the virtual environment on the x, y, and z plane. A human figure was created and scaled to match the illustrations imported into the virtual environment. (*Refer to screen shot 4.*) Using the illustrations as a backdrop to the human figure and the human interface tools, the body joint angles were manipulated to replicate the body angles of the NBP. The posture was saved in JACK and was placed in a human posture library. [3]

Results

The results of the analysis may be explained according to the operations scenarios that were modeled. For the QMI installation and checkout and SACA insertion and removal tasks, the analysis indicated that there is adequate clearance, accessibility, and full size range accommodation. Various screen shots show that the work envelope is appropriately designed to support both the 95th percentile male and the 5th percentile female and to allow reach access as required. Also, the visual

However, with regard to fasteners and connectors design, the analysis indicates that the design favors right-handed function and does not sufficiently

accommodate use of the left-hand. An example is evident in screen shot 5, which shows that left-handed mating/demating of SACA cable connectors is hindered.

For the gas bottle drawer removal task, assessment of the body envelope and reach accessibility pointed to there three design considerations:

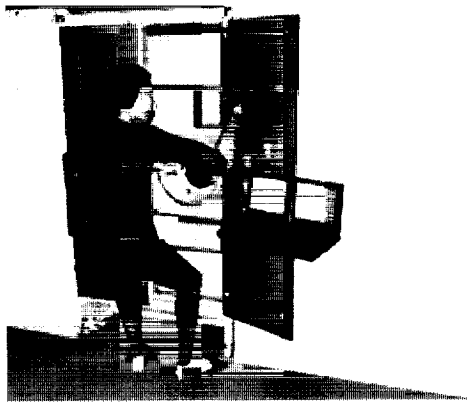
- 1) The gas bottle drawer design did not meet the requirements of SSP 57000, Revision C, 3.1.1.7.1. The knobs and handles protrude beyond the limits of the rack door panel. A suggested solution was to redesign the drawer panel to include removable handles such that the handles meet the requirements of 3.1.1.7.2 for semi-permanent protrusions. Refer to screen shot 6.
- 2) The design did not meet the requirements of SSP 57000, Revision C, 3.12.2.2. The original design of the drawer had one handle on each opposite end of the front drawer panel. This placement of the handles was awkward in that the human model was required to bend deeply at the knee and waist to secure the knobs to the valves, grasp a handle with each hand, then pull the drawer with some torque.
- 3) The design did not meet the requirements of SSP 57000, Revision C, 3.12.2. The foot restraint locations as suggested in the previously referenced document [1] do not allow an adequate body envelope or appropriate accessibility for the male or female stature while attempting the gas bottle drawer removal task. The suggested solution was to redesign the drawer with a removable horizontal handle and include in crew procedures use of the door panel bar (shown in screen shots 7 and 8) for balance. With such, the crewmember may remove his/her feet from the foot restraints but still have leverage and balance to perform the task by grasping the door panel bar while removing the drawer.

Summary

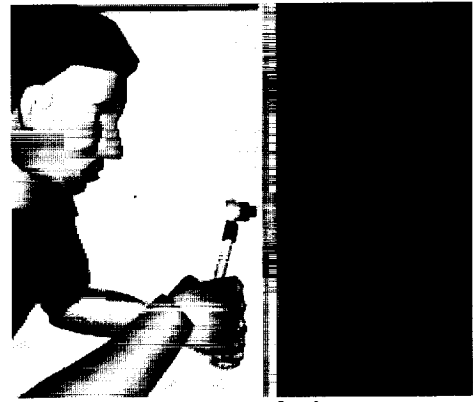
In summary, Transom JACK was used in the human engineering evaluation of the Materials Science Research Rack-1 and Quench Module Insert because of its ability to correctly model anthropometric body measurements and the physical behavior of crewmembers working in microgravity. The model allowed evaluation of crewmember interaction with hardware through task simulation. The results led to some design recommendations to ensure adherence to the Pressurized Payloads Interface Requirements Document – International Space Program, Revision C (SSP 57000).

References

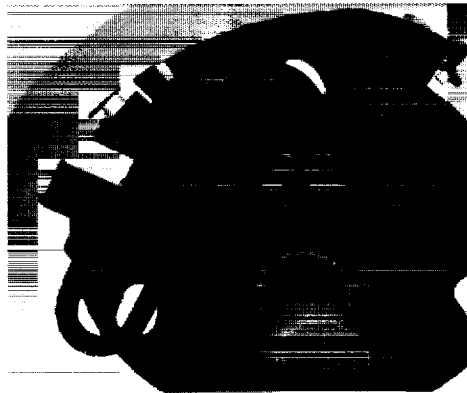
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2. MSFC-DOC-2873. Quench Module Insert Operations Concept. July 1, 1998. NASA, Marshall Space Flight Center. Huntsville, Alabama.
3. Hutchinson, S. L. and Alves, J. (1999). Using virtual simulations in the design of 21st century space science environments. Proceedings of the National Society of Black Engineers Alumni Extension 1999 Technical Professionals Conference, Kansas City, MO, 8-15.
4. SSP 57000 Revision C. Pressurized Payloads Interface Requirements Document: International Space Station Program. April 28, 1999. NASA, Johnson Space Center. Houston, Texas.
5. EAI Transom Technologies, web-site www.transom.com , "Applications"



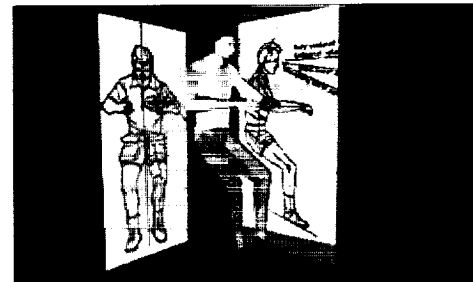
(1) Secure IP to door



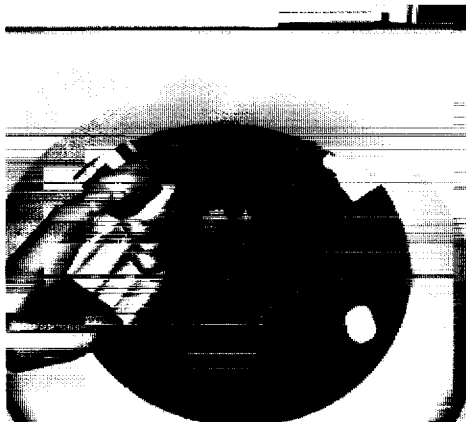
(2) Ratchet IP to drive mechanism



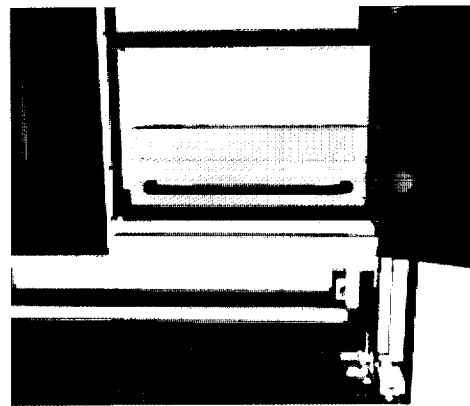
(3) Left hand access - connecting a QD



(4) Looking out of JACK's eyes at hardware



(5) Neutral body posture of JACK



(6) Gas bottle drawer - Redesign of handle



(7) 5th percentile female loosening fasteners - 1



(8) 5th percentile female loosening fasteners - 2