Human Centered Hardware Modeling and Collaboration

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Abstract—In order to collaborate engineering designs among NASA Centers and customers, to include hardware and human activities from multiple remote locations, live human-centered modeling and collaboration across several sites has been successfully facilitated by Kennedy Space Center. The focus of this paper includes innovative approaches to engineering design analyses and training, along with research being conducted to apply new technologies for tracking, immersing, and evaluating humans as well as rocket, vehicle, component, or facility hardware utilizing high resolution cameras, motion tracking, ergonomic analysis, biomedical monitoring, work instruction integration, head-mounted displays, and other innovative human-system integration modeling, simulation, and collaboration applications.

Keywords—Biomechanics, Vicon, Motion Capture, Virtual Environment, Systems Engineering, Collaboration

I. INTRODUCTION - EXPERTISE AND TECHNOLOGY

In order to collaborate engineering designs among NASA Centers and customers, to include hardware and human activities from multiple remote locations, live human-centered modeling and collaboration across several sites has been successfully facilitated by Kennedy Space Center. The focus of this paper includes innovative approaches to engineering design analyses and training, along with research being conducted to apply new technologies for tracking, immersing, and evaluating humans as well as rocket, vehicle, component, or facility hardware utilizing high resolution cameras, motion tracking, ergonomic analysis, biomedical monitoring, work instruction integration, head-mounted displays, and other innovative human-system integration modeling, simulation, and collaboration applications. Computer modeling of virtual environments and objects motion capture is used to monitor real-time human movements along with the ergonomic software to view and provide actual biomechanical data for Real-time assessment of manufacturing processes within a collaborative virtual environment. Using state-of-the-art motion capture tools to examine human, machine, and environment interfaces provides exceptional insight into the products and processes. The lab creates immersive virtual reality environments from customer's CAD data to capture biomechanical data of humans while performing flight hardware assembly and maintenance functions. Figure-1.
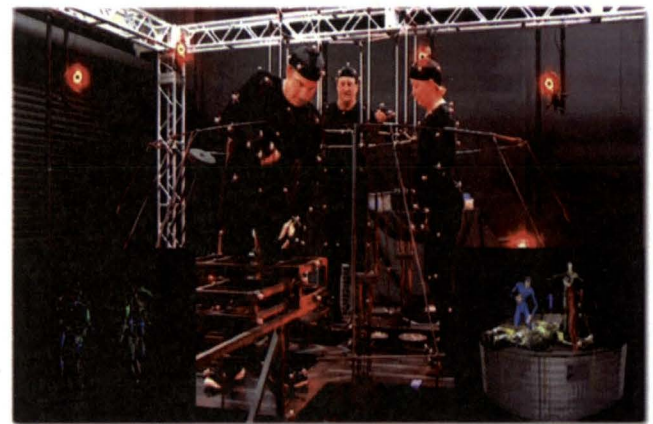

Figure 1 Motion Capture Lab

II. CAPABILITIES

The lab has tracked up to three people at the same location with four objects also being tracked in the environment. There has been up to five remote locations connected together for an fully immersive collaborative environment. Engineers and Technicians are brought together from different centers (locations) to verify hardware design and process flow before the hardware is built. This provides an excellent pre-task briefing. Not only are we looking at the stresses on the human body but also human/machine interface, collision detection, and 1st person view. The Capabilities of the lab are:

- Live Motion Captures
- Tracking of 1 or more humans / objects with physical mock ups
- Real-time and Infinite Playback of Simulations
- Virtual Environments derived from CAD models
- Biomechanically correct Avatars
- Collaborative Environments between multiple locations

- Real time design assessment and process analysis
- Pre task orientation
- Human Factors Analyses and Risk Identification
- Human/Machine Interfaces
- Collision Detection
- First Person Visual Field of View
- 3D Simulation Videos

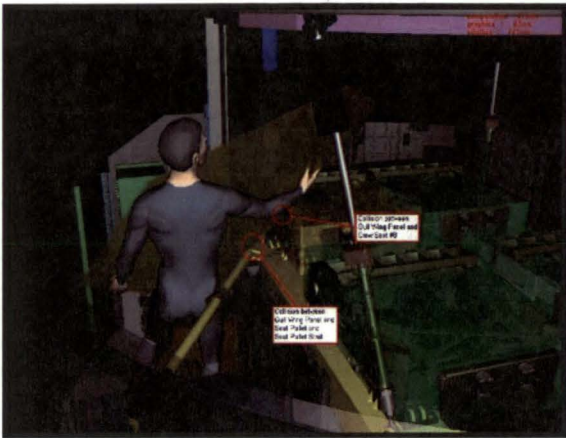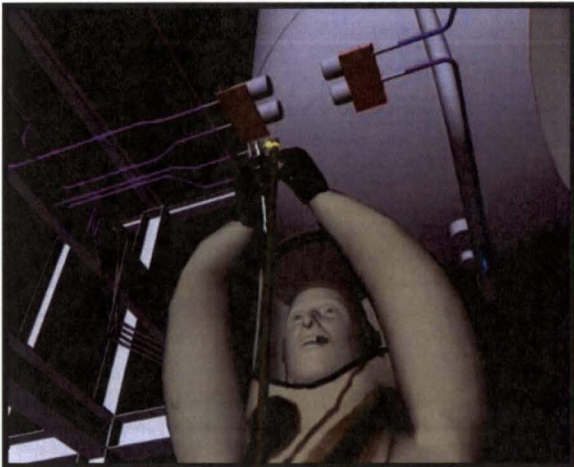Figures 2, 3, and 4 show some human and hardware modeling.
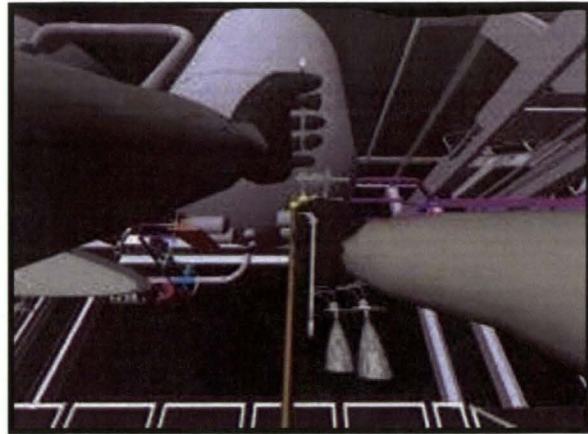

Figure 2

Figure 3

Figure 4

III.   COMPONENT TECHNOLOGY

The use of movable cameras helps reduce occlusion. Along with the full suit the lab uses rigid body markers, or a separate HMD/glove set up.

Siemens Jack allows accurate avatars connectivity with Vicon and gloves. The 1st person view that allows HMD usage and real-time ergonomic assessment which can be seen via live streaming .

The Motion Capture System (Vicon™) includes:

- (34) cameras on a 20'x20'x12' Truss
- Rigid body markers on HMD and objects
- (54) marker set on humans
- (1) pair of Cyber Gloves.

Figures 5, 6 and 7 show the use of HUD and motion capture.
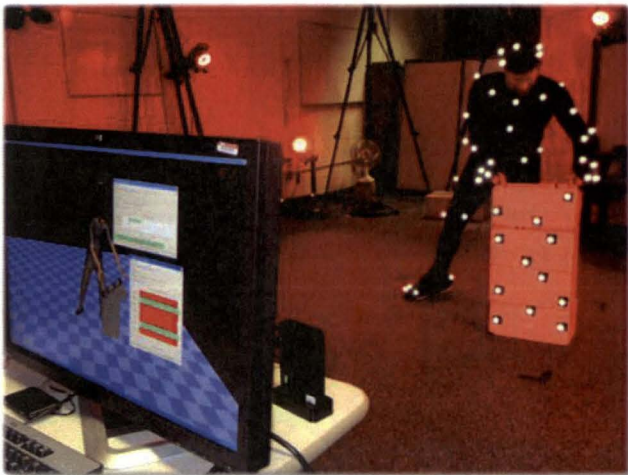

Figure 5

Figure 6

Figure 7

Skilled team of engineers and analysts use the HEMAP integrated system to perform in-depth analyses of the project. Human interface and ergonomics analysis can provide valuable answers before finalizing designs and before committing resources. Risks are identified before equipment or hardware are built, which is cost efficient and valuable in the mitigation of risk

Results can successfully prevent risks and injuries to workers, while helping design engineers create safer equipment and hardware, through the use of motion capture cameras and equipment

The analysis includes: Lower Back Compression, Fatigue & Recovery, Static Strength Prediction, Energy Expenditure, Working Posture, Rapid Upper Limb Assessment, Manual Handling Limits.

The process includes, the Computer Science and Human Factors Engineers, the Project Requirement Identification, the CAD models to JT files conversation, the Virtual Environment creation, the Mock-up creation, if required, the Engineers' & Technicians' measurements to create accurate Avatars, the Cyber Gloves and HMD calibration, the Marker placement on Participants, and the Physical and Virtual World alignment. Figures 8 and 9 shows some of these processes as they were performed.

Figure 8

Figure 9

IV. VALIDATION

Various testing of the overall HEMAP system was performed. Visualization tests were performed to make sure original motions matched the simulated views. Dimensions of objects and participants were compared to measured values of the objects and avatars in the virtual environments. Human factors data for lower back analyses were compared to academia models, while NIOSH lifting motion-captured task compared to manual and electronic calculations. Overall, the HEMAP system functionality and repeatability were tested by applying the same posture and weight load to participants, collecting 72 data points, and analyzing to demonstrate consistency. In addition, processes were documented to apply consistent HEMAP approach to project assessment needs.

V. PROCESS FLOW

The process flow starts with the real time task, then a simulated task is done with the motion capture. Ultimately this motion capture is used to create a human model within the CAD model, and the stresses can be calculated using Jack. Figure-10.
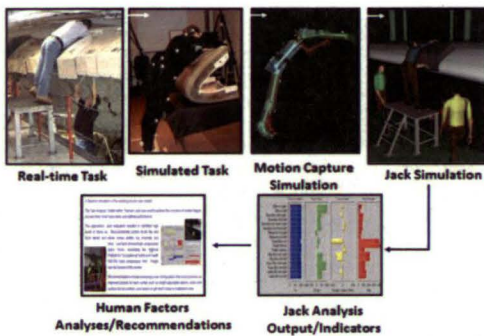

Real-time Task   Simulated Task   Motion Capture Simulation   Jack Simulation

Human Factors Analyses/Recommendations   Jack Analysis Output/Indicators

Figure 10

VI. PROJECTS:

The reach and posture project looked at the Installation and Removal of Wing Leading Edge Panels. The goal and problem was to identify risks associated with the task. The analyses and findings were eexcessive reach, greatest forces to ankles and back. The rrecommendations were to modify a stand for height adjustability and for larger work surface to allow for 2-person lift. The rresult was a new 2-person stand with height-adjustability implemented.

The posture and fatigue project looked at the window polycarbonate cover installation. The goal and problem: was to develop an ergonomic solutions to improve installation

process. The analyses and findings identified high levels of stress on musculoskeletal system and excessive fatigue on the body. The recommendation was to implement support fixture to attach to bottom of panel and use of a back support, and to provide for breaks during long-duration task. Figures 11 to 14 show the actual activity, the motion capture, the Vicon model, and then the virtual human in the CAD environment.
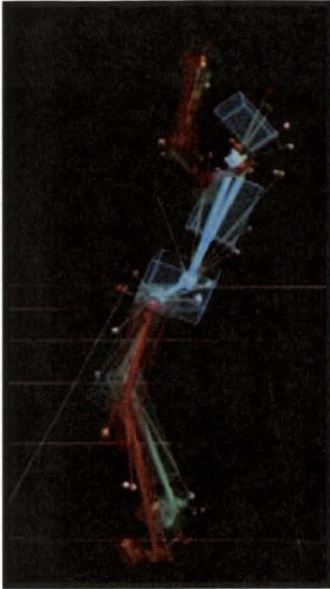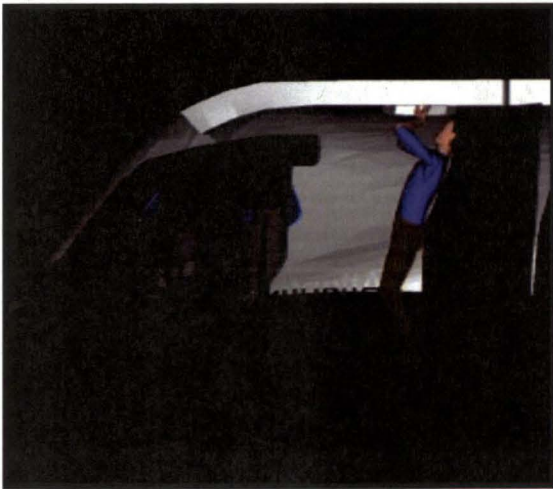

Figure 11

Figure 12

Figure 13

Figure 14

Figure 15

Figure 16

The lifting and postures project looked at the installation of environmental controls and life support systems components in Crew Module. The goal and problem was to identify risks associated with the procedure. The analyses and findings determined that repetitious lifting and awkward postures promoted strained lower back and upper arms. The recommendations were to use of lifting aids as well as platforms to reduce awkward bending. Figure 15 and 16 show the humans immersed into the CAD models.
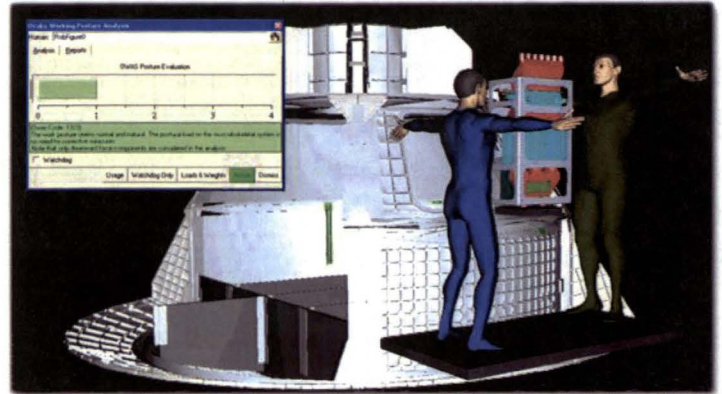
The wire harness assessment project evaluated if a technician in the current Bulkhead configuration could reach their hands around and along the harness path to install the wire harness. Furthermore, can it be done without damaging the critical ETL system, and without applying weight/pressure on the Bulkhead. The analyses and findings showed some scenarios that were unfeasible due to the Technician's inability to reach the wire harness and the Technician's repeated collision between arm/hands and Pyro Lines and Low visibility. The recommendations were that Technicians should be allowed to place one hand on the bulkhead for balance during installation, or at the very least an installation aid should be utilized. Figure 16 and 17 show the use of HUD and motion capture.
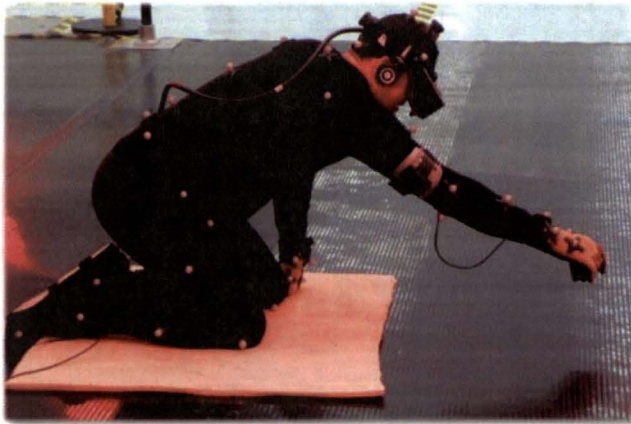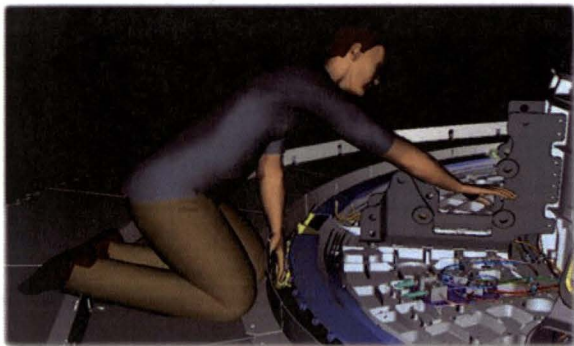
Figure 17

Figure 18

I. CONCLUSION

Motion capture and heads up displays which immerse the human into the CAD models have been successfully used for human factors analysis at KSC for the design of flight hardware and the design of operational task for ground processing.

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