1-G Human Factors for Optimal Processing and Operability of Ground Systems up to CxP GOP PDR

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Abstract— During the mid stages of design development, up to Constellation Program (CxP) Preliminary Design Review (PDR), the requirements for leveraging 1-G human factors for optimizing ground processing of Flight Hardware were mature for levels - 2, 3, 4, and 5. This paper gives an overview of the accomplishments achieved during that time. The main focus of this paper will be on the CxP Ground Operations Project human factors engineering analysis process using a Human Factors Engineering Analysis Tool (HFEAT) for developing the level- 5 requirements effecting the design development of the subsystems for Ground Support System (GSS), and Ground Support Equipment (GSE). [1 2]

TABLE OF CONTENTS

1. INTRODUCTION 1
2. HUMAN FACTORS REQUIREMENTS & PROCESS 1
3. SUB-SYSTEMS ANALYSIS USING HFEA TOOL 2
4. HFEA TOOL AND PROCESS 3
5. REQUIREMENT EXAMPLES FROM HFEA 3
6. LESSONS & FUTURE PLANS 3
7. CONCLUSION 8
REFERENCES 8
BIOGRAPHY 9

1. INTRODUCTION

Up to CxP PDR, the systems engineering requirements for Levels 2, 3, 4 and 5 for 1-G human factors was improving. The levels are defined as: Level 2 is Program, Level 3 is project, level 4 is project managers for elements, and level 5 is design engineering. Elements can be Vehicle Integration Element (VIE), Mobile Launcher Element (MLE), or Launch Pad Element (LPE).

Concerning this the CxP Ground Operations Projects level 3 documents pointed to the level 2 CxP Human Systems Integration Requirements (HSIR) document for designing flight hardware for ground processing, or for designing ground hardware for flight crew activities; or to the NASA STD 5005 for the GSE used in ground processing. The HSIR had specific requirements and verifications, but the NASA STD 5005 human factors section pointed the FAA HFDS. The FAA HFDS has 15 chapters, and within each chapter there are many standards. The level 4 requirements documents were for each of the GOP Elements, such as Mobile Launcher Element, Vertical Integration Element, etc. And the requirement flow from Level 3 to Level 4 did not add more definition to the FAA HFDS human factors requirements. Thus it was Level 5, Design Engineering's responsibility to define the human factors requirements from the FAA HFDS for each CxP GOP subsystem. This great task was efficiently and effectively accomplished by developing and using a Human Factors Engineering Analysis tool.

2. HUMAN FACTORS REQUIREMENTS & PROCESS

Per KDP P-2713 Rev. B, A Human Factors Engineering Analysis (HFEA) was performed for all CxP GOP Subsystems. The analysis was performed by qualified Human Factors Engineers using an approved Human Factors Engineering Analysis Tool. The analysis included a selection of applicable Federal Aviation Administration Human Factors Design Standards (FAA HFDS), and a selection of L3 Systems Requirements Document gap human factors requirements for Tool Clearances, Lifting Limits, Connector Miss-mate, and Personal Protection Equipment (PPE).

3. SUB-SYSTEMS ANALYSIS USING HFEA TOOL

For the CxP GOP there were over 30 subsystems that were given a human factors engineering analysis. Examples of these subsystems are: Crew Access Arm, Handling and Access, Umbilicals, etc. See figures 1, 2, and 3.

[1]978-1-4244-7351-9/11/$26.00 ©2011 IEEE.
[2] IEEEAC paper #1001, Version 1, Updated March 24, 2010

Figure 1 ML Crew Access Arm for Capsule

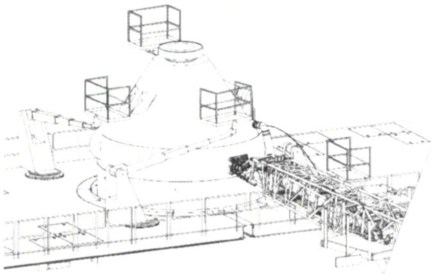

Figure 2 VIE Handling and Access & ML Umbilical for Capsule

Figure 3 VIE Handling and Access for Capsule

As the designs were evolving, the HFEA was updated during the design review stages, and when changes to design led to any human factors issues. This involved review of the subsystems documentation, attending the (SDRP) System Design Review Process meetings, splinter meetings with the Lead Design Engineers (LDE) and systems engineers (SE). An initial kick off meeting is set with the LDE at the 30% DR. This is to introduce to the LDE, the HFEA process, what is their expected gain from the HFEA to their subsystem, and to point out any human factors issues as early as possible. This type of kickoff analysis is similar to what took place during the pilot study [3].

4. HFEA TOOL AND PROCESS

The HFEA analysis begins at the Subsystem 60% and is updated at each of the Subsystem 90% Design Review, and 100% Design Release. The analysis was performed by qualified Human Factors Engineers using an approved HFEA Tool. During the analysis, the FAA requirements and Systems Requirements Document (SRD) gap requirements were reviewed and applied to each individual Subsystem where applicable. These requirements and standards are summarized in a HFEA Report. Information in the Report includes; which HFE prepared the report and their organization, and who concurred the report, the SEs name and concurrence, and the LDE's name. Once the standards are selected from each chapter of the FAA HFDS they are summarized in a HFEA Report. That report is effectively a specific set of human factors requirements for a specific subsystem.

Within the HFEA Tool, there are several tabs to complete the HFEA for a specific subsystem. And within each tab several fields to complete. Figure-1 is a snapshot of the tool showing the tabs at the bottom and the fields to complete within one tab. The tab shown in Figure-1 is the FAA chapter "Designing Equipment for Maintenance". Starting from left to right is the sequence of completing the HFE analysis. From the first left tab there is the subsystem data. This data is; the subsystem name, the subsystem abbreviation, the lead designers name, the systems engineers name, the section heading, and the elements affected (MLE, LPE, VIE, etc.) In the tool, most of this input information is provided and the HFE simply just needs to select the subsystem. And the rest of the information loads up automatically. The next tap is the human interface. This tab describes all of the human interface areas. Once all of the human interfaces have been determined by understand the human activities, for all operations; Assembly, Installation, Nominal Use, Inspection, Maintenance, Off-Nominal use, Emergency use, Disassembly, and Disposal, then the HFE can proceed to the following tabs, which are basically the FAA HFDS chapters (General, Automation, Designing Equipment for Maintenance, Displays and Printers, Controls and visual indicators, Alarms audio and voice, Computer human interface, Input devices, Workplace design, System security, Personnel safety, Environment, Anthropometry and biomechanics, and User documentation). There is also a tab for any extra requirements (gap) dictated by the program or project, and there is a OSHA tab that includes the human factors OSHA type requirements.

5. REQUIREMENT EXAMPLES FROM HFEA

Figure 1 shows three requirements that were generated in the "Designing Equipment for Maintenance section". The following will explain all three of these by explaining each column input. Before describing the inputs for each column, the column inputs are defined as: Human/System Interfaces, Issues, Requirement Source (mostly FAA), Requirement Section Title, Requirements Sub-Section Title, Requirement [R], Conditions [C], Possible Consequences [PC], Processing Phase (PP); (Assembly/Installation, Nominal Use, Inspection, Maintenance, Off-Nominal Use, Emergency Use and Disassembly/Disposal), Requirement Satisfied, Primary Verification (Inspection, Analysis, Demonstration, Test), Risk Priority Rank Consequence, Risk Priority Rank Likelihood (RPRL), Risk Priority Rank Product, Why Non-Compliant, Potential Recommendations, and Notes.

Now for the three requirement examples provided in figure-1, the three Human/System Interfaces from top to bottom are:

- CAA actuation motor,

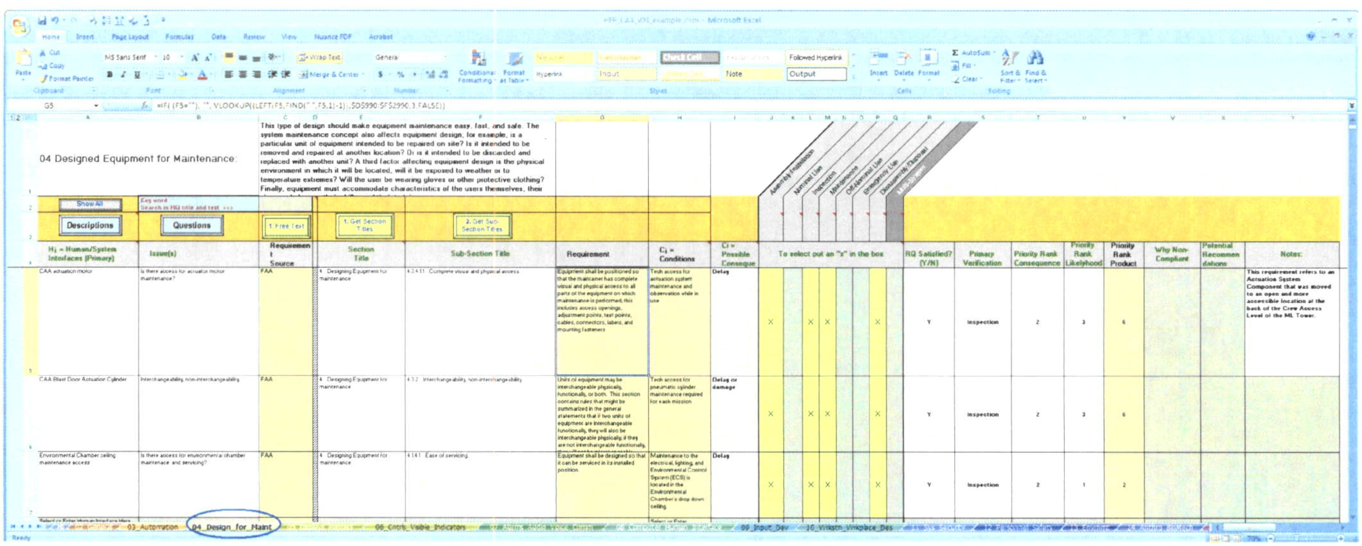

Figure 4 HFEA Tool showing the three requirement examples in the "Designing Equipment for Maintenance" tab

- CAA Blast Door Actuation Cylinder,
- and Environmental Chamber ceiling maintenance access.

These human interfaces were previously determined by understanding all of the human activities through conversations with LDE and operators in relation to this subsystem. The activities include all launch processing activities: nominal, off nominal, emergency, maintenance, rocket assembly, inspection, etc. These interfaces were previously uploaded in the HFEA in the 2nd Tab by the HFE. Also keep in mind, although this example describes the first three requirements in the tool at the same time, in reality the HFE only develops one requirement at a time.

The next column to complete after the Human/System Interfaces for these three requirements is the "Issues" column. The issues for these three human interfaces in order are;

- "Is there access for actuator motor maintenance?"
- Interchangeability/non-interchangeability,
- and "Is there access for environmental chamber maintenance and servicing?".

These interfaces were determined by The FAA requirement section title, which is of course Designing Equipment for Maintenance.

The Subsection titles for these three issues were;

- 4.3.4.1.1 Complete visual and physical access.,
- 4.3.2 Interchangeability, non-interchangeability,
- and 4.1.4.1 ease of servicing. The requirements for these subsections were:

For the first issue; Equipment shall be positioned so that the maintainer has complete visual and physical access to all parts of the equipment on which maintenance is performed;

this includes access openings, adjustment points, test points, cables, connectors, labels, and mounting fasteners.

Second Issue; Units of equipment may be interchangeable physically, functionally, or both. This section contains rules that might be summarized in the general statements that if two units of equipment are interchangeable functionally, they will also be interchangeable physically; if they are not interchangeable functionally, they will not be interchangeable physically.

And Third Issue; Equipment shall be designed so that it can be serviced in its installed position.

The three possible consequences are for the three above issues are;

- Delay,
- Delay or damage,
- Delay.

All three of these requirements had the same processing phase.

For the three issues the processing phase were;

1. Assembly/Installation
2. Inspection
3. Maintenance, and Disassembly/Disposal.

All three of these were found compliant during inspection of the design drawings. And the Risk priority rank products were; 6, 6, and 2. There was one note for the first issue, that note was, "This requirement refers to an Actuation System Component that was moved to an open and more accessible location at the back of the Crew Access Level of the ML Tower."

These were just three HFEA requirements derived out of one chapter of the FAA HFDS. For the complete HFEA requirements for the subsystem, all standards from FAA are considered and the applicable standards become HFEA requirements for that GOP Subsystem. See figure 5 and 6 for example of CAA actuator motor maintenance access.

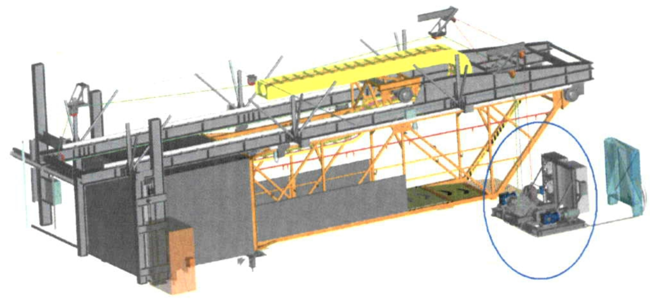

Figure 5 CAA Mechanisms, Actuator Motor "shown in circle"

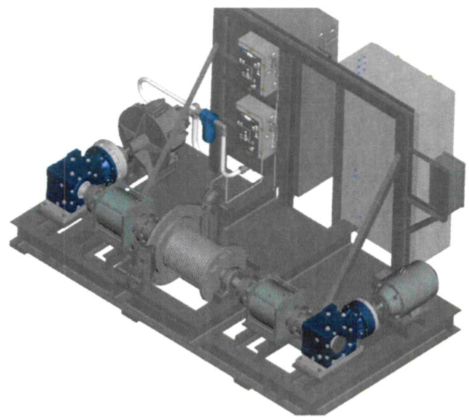

Figure 6 CAA Actuator Motor and mechanisms

Once all of the tabs are completed, then a PDF report can be generated using the "Make Report" tab. The report sorts out the requirements putting the non-compliant requirements at the top. All of the data determined during the HFEA in each tab is given in the report. This same report can be used by the HFE during the next stages of design development to ensure that the design reflects the human factors concerns that were determined in the HFEA. See figure-2 for a snapshot of the first page of the HFEA Report for CAA.

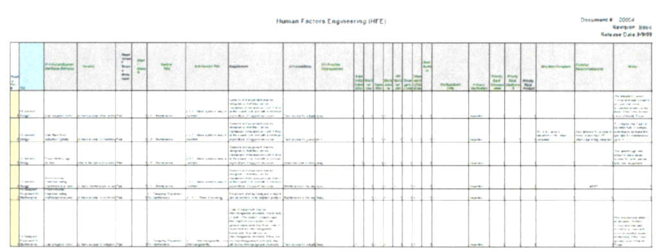

Figure 7 Snapshot of CAA HFEA Requirements Report

6. LESSONS & FUTURE PLANS

This section gives lessons and future plans from the future plans from the "1-G Human Factors for Optimal Processing and Operability of Constellation Ground Systems" paper See [2], and from the current effort. All of these new lessons will be documented into the NASA Integrated Lessons Learned system. http://nen.nasa.gov/portal/site/llis/LL/

Design Engineering

(1) Lesson: NESC pointed out several mishap lessons learned, that helped improve the HFEAs, and the Subsystem designs. Future plan: Continue and elevate this process and collaboration with NESC.

(2) Lesson: The human factors engineering tool , analysis, and report, proved to be an efficient and effective means to develop HFEA for the 60% and 90% and 100% design packages . Future Plans: Continue to use and improve the process and tool.

(3) Lesson: It was effective to include the HFAE tool and process in the GOP L3 Systems Engineering Management Plan (SEMP). Future Plans: Insure that the factors assessment process and tool is included in the L3, L4 and L5 SEMPs.

(4) Lesson: Human Factors Engineer – Human interfaces and ergonomics was included into the KSC KDP-P-2713 Technical Review Process. Future Plans: Ensure that human factors is included in the KSC Technical Review Process for future Programs/Projects at KSC.

(5) Lesson: NASA-STD-5005C was accepted by the CxP, and the FAA Human Factors Design Standard was incorporated into the human factors engineering tool. Future Plans: Collaborate with FAA for further development and applications of the HFEA Tool and Process.

(6) Future Plans: Make use of human factors principles and analysis during the ground processing activities to prepare flight hardware for the CxP test flights.

(7) Future Plans: Continue to prove the usefulness of human factors so that it will be commonly accepted into the work break down structure at KSC.

(8) Future Plans: Improve the HFEAT by incorporating into the tool; design solution lessons learned from KSC Engineering use of HFEAT, NASA programs, industry, etc.

(9) Future Plans: Employ the human factors systems engineering processes and lessons learned from Ares-I to Heavy Lift Vehicle (previously Ares-V).

(10) Lesson Learned: The NASA CxP program level human factors requirements document HSIR greatly promoted better human factors Systems Engineering and Integration. This improved the integration between ground systems, launch vehicle, and crewed vehicle designs for ground processing. Current and Future Plans: Flight Hardware ground processing requirements and GSE requirements are currently making their way into NASA Standard 3001 volumes two and three. Combining the Human Factors (HF) standards needs for; crewed vehicle, launch vehicle, and ground processing of these vehicles, in the Level 1 NASA STD 3001, promotes integration of NASA HF and improvements to design, SE&I processes and other methodologies, to all NASA programs. Additionally, including launch processing into the NASA STD 3001 and applying these requirements to programs, gives us the opportunity to capture the lessons learned from those programs back into a one stop shop NASA human factors standard - NASA STD 3001. Much like the requirements and standards for flight crew have improved over the years in the NASA STD 3000, the standards and requirements for ground processing can be monitored and improved through the use of a single standard, NASA STD 3001. Since NASA STD 3001 is specifically a human factors document and also a Level 1 document, this is a much better option than to house the ground human factors requirements in the NASA-STD-5005, 512-SM, L3 GS-SRDs,or revise the GS-HFRD. See [7]

(11) Lesson: Early collaboration and planning between the flight and ground hardware designers for human factors engineering analysis (HFEA) is necessary. And having a dedicated team of HFE was very effective in defining and improving the HFEA process. Future Plans: Employ qualified human factors person/s on each Subsystem team from the beginning of the Project. Having a Human Factors engineer as part of the design team would help the team to develop design solutions to comply with any requirements at the early stages, and would help the HF engineer do a thorough evaluation of the subsystems during their development.

(12) Lesson: Developing individual HFEA reports with the LDEs and SEs on their subsystem was very effective in bringing human factors awareness to the LDE/SEs.

(13) Lesson: Originally the HFEA Tool was intended to be used by systems design engineers, and reviewed by human factors engineers [4]. But the process evolved and improved where the human factors engineers were involved with the design teams mostly through the LDEs and SEs. Some HFEA involved the human factors engineer to be included and attend the Subsystem team meetings. Future Plans: It was realized by attending the subsystems design team meetings, there would have been a better relationship

with the design teams and the HFEA would have been more effective. This approach is more feasible now that there is a HFEA Tool, and process.

(14) Have a kickoff human factors meeting with the SE and LDE earlier in the design process at 30% so they can get an understanding of the HF requirements, and processes. Since there is limited design information at the 30% review, the initial HFEA should be done a few weeks after the 60% review where most of the human factors questions can be addressed and tracked at the 60%, still leaving enough time for the designers to make improvements from 60% to 90%.

(15) Lesson: Off-base human factor support personnel was not the best approach for providing human factors expertise. The HFEA Tool is a great help and facilitates doing the assessment. It would have been very difficult to perform this sophisticated analysis without this tool.

(16) Lesson and Future Plans: Following the 100% HFEA, there should be a Human Factors requirements verification done by an independent auditor (HF person) along with Safety after the subsystems are installed and operating. This will verify that the "as built" matches the "as designed" and that all of the HF requirements in the HFEA have been satisfied. The HFEA report generated for each subsystem can be used as a verification checklist. There should be something to trigger an audit.

(17) Lesson: When reviewing the HFEA report, the concise compliance notes in the notes sections of the HFEAT worked well. But when considering a process activity, it was difficult to determine the requirement compliance through the two dimensional drawings, or documents. Human activities are 3D, thus 2D drawings can be misleading. Future Plans: Infuse; 3D static models, 3D motion models, motion capture mockups, physical mockups, which include the human and the HF areas of concern into the design process. Also, include these into the HFEA report. Another solution is to improve the 2D models so they better capture and broadcast the HF concerns. Pro E Product used in Design Engineering will have capability for including human in 3D models generated by CAD models.

(18) Lesson: The HFEAT report is basically a tailored requirements document for each subsystem, which the LDE agreed to the requirements in the HFEAT report. In the notes section the compliance is described. Also in the notes section, at early reviews, the non-compliances with a human factors design solution can be recorded so it can be met at before the next or final review. Additionally the LDE could provide comments to the HFE to be added into the notes section, pointing to the drawings that indicate how the FAA requirements will be met.

(19) Lesson: The tool worked extremely well and was developed with very little funding. During this "pilot" use of the tool areas for improvement were discovered. Future Plans: There were some areas of the tool that are inflexible and need improvement: Deletino of rows or columns, requirement section drop down list, OSHA/HF section, columns for closure notes and for objective evidence for requirement compliance.

(20) Lesson: The tool was created in excel spreadsheet with macros, and is only used for one Sub-system at a time. Future Plans: A web based tool would increase speed, allow integration across subsystems, more interactions with outside information, and allow design solutions to be recorded in a database for other HFEAs.

(21) Lesson: The process of first getting with the LDE to understand the subsystem and introducing them to how human factors can help their system, then looking at documents and drawings, then populating the HFEAT with possible requirements, and then following up with the LDE to get agreement on the requirements and compliance rating worked well. Face to face meetings were invaluable in enhancing communications. Phone calls and discussions with the LDEs were also helpful. Overall the process brought a better HF appreciation/understanding to the LDE, and at the same time improved the design of the subsystem for maintenance, inspections, operations, etc.

(22) Lesson and Future Plans: A more defined breakdown of all the subsystems as a whole would have been helpful to see the "big picture" and the boundaries of the individual subsystems. At times it was difficult to decide what hardware went with which subsystem.

(23) Lesson: Responsibility of the interfaces between subsystems were not always clear. For the most part the Subsystem LDE or SE would take responsibility to ensure that the interfacing subsystems were meeting the human factors concerns of their subsystem. For example: lighting, handling and access, KGCS (communication connections) Future Plans: A web based HFEA Tool/Database would allowed all of the Sub-systems to be tracked simultaneously which would help the HFE to keep track of the interfaces between subsystems.

(24) Lesson: The use of several HFEs. Because of the schedule it was a benefit to have several HFE to keep up with the schedule. Also it was benefit to have a variety of expertise evaluation the tool and processes. Lessons learned were communicated across the team during the regular scheduling meetings, and through office collaborations. Future Plan: Have separate meetings dedicated to sharing HFEA experiences with

the tool, and with the results of each analysis. For example, peer reviews of the assessments.

(25) Lesson: Scheduling of assessments should be laid out according to the subsystem milestones. There were also requests for preliminary reports to be included in the data package. Future Plan: A better overall approach would be to do a preliminary checklist assessment/introduction at the 30% package, a more thorough HFEA at the 60% package (several non compliances, but they are being tracked by LDE/SE and HFE), and a final HFEA assessment at the 90% (less non compliances but most have been meet) and 100% (all non compliance have been resolved) phase. Also continual evaluations with the design team at their regular meetings is preferred, if the HFE is only able to rely on design drawings; sufficient time should be allowed for the Subsystem documents to be populated in the database before performing the HFEA. Longer time frame for the more complex or single assessment subsystems (where only a 90% or 100% assessment is done).

(26) Lesson and Future Plan: Although there was human factors expertise in L3, there was not adequate expertise in L4, Projects (Mobile Launcher, Launch Pad, Vertical Integration, etc). At the same time, in the early stages there was a lack of resources in L5. This delay in HFE resources in L5 required a buildup of HFE to perform the HFEAs. There should have been integrated communication between human factors resources at L3, L4 and L5. As well as better integration of a GO HF team (L3, L4, L5) designs with Orion Projects, and Ares Projects. See [5] and [6]

(27) Lesson and Future Plan: Human Factors was not an embedded in the SE&I work breakdown structure (WBS) in L3, L4, and L5. Although Human Factors was embedded in L3 SE&I in the very early stages, it soon was relocated into Project Integration, then to Integrated Operations. In L4 there were no Human Factors POCs. In Level 5 Human Factors was housed within Engineering Management and Integrated Services. See [7] and [8] about embedding HF into SE&I and WBS.

(28) Future Plan: To improve scheduling, the different complexities of the various subsystems could be a way to approximate how much time is given to complete an assessment. Some subsystems were relatively small (few panels, components) and some were very complex with interfaces to multiple other subsystems.

(29) Future Plan: An integrated HFE approach after the individual subsystem assessments are completed at the 60% would be prudent to uncover potential conflicts early. And after the 90% assessments are complete for all subsystems, an overall, integrated evaluation would help tie individual findings back into the "big picture" before the 100%.

(30) Lesson: It was discovered that certain areas of (1) FAA were not applicable to launch processing, or that (2) other KSC standards already adequately covered the same areas as FAA, (3) or that areas were already covered by other HFEAs. Future Plan: These aspects should be sorted out and incorporated into an improved tool, so the HFEA does not use time going through the FAA requirements that do not apply to launch processing, and also to make sure the human factors type requirements in the KSC standards are being addressed by the HFE, and so requirements are not duplicated across HFEAs. Example; (1) Security type requirements in FAA are already covered by KSC Security (only the human factors aspects of Security should be addressed in HFEA), (2) KSC standards for labels, cross connections covered in KSC-STD-Z-0006B, etc. need to be tracked by the HFE. (3) the Screen Designs for each Subsystem is covered by a dedicated HFEA for screen designs for each Subsystem through the Integrated Launch Operations Application (ILOA) effort, and there is a separate HFEA for Kennedy Ground Control Subsystem (KGCS). There are many subsystems that interface with the KGCS.

(31) Lesson: It is important to continually update the HFEA schedule as the master Subsystem schedule changes. This is important to have good timing with the Subsystems.

(32) Lesson: Post-review of the results would be useful to produce lessons learned showing any trends that may have been uncovered during the analyses, and applying these early to improve the process. For example, it was discovered that the area of labeling could use some improvement. The need for labels and the proper use of labels from past experiences was not well documented into the HFEAT.

(33) Lesson: Have as much information as possible prepared prior to beginning the effort. For example, during the 30% kickoff meeting with the LDE/SE the HFE should have a complete process and products defined. The kickoff meeting is mainly to introduce the process to the LDE/SE.

(34) Lesson: The gap requirement flow down from L3 was addressed for each Subsystem in the HFEA, some of the HFE addressed the gap requirement design issue using a less adequate FAA standard. Because qualified HFE were performing the HFEA the intent of the issues was met through the analysis. Future Plan: For requirements tracking reasons, it would have been better if the gap requirements were pointed out instead of the FAA requirements in some of the HFEA reports.

(35) Future Plan: The risk analysis information sheet in the HFEAT needs to be updated to include personal injury and damage to hardware.

(36) Lesson: Although the HFEA were deliverables to the SDRPs and ERDs, there was a lack of formal integration of the HFE at these meetings for the Subsystems. For the most part, HF issues that were not easy to resolve were dealt with off line between the LDE and SE, not at the SDRP or at ERBs. Although this was effective, some of the issues would have been resolved earlier and better through formal review at the Design Meetings. Thus it was not as effective as it would be if HF input was regularly included during the Reviews. This process improved for the CCCE HFEA for displays. Where for each Subsystem for CCCE at the Technical Integration Panels was required to have a slide for human factors. Also, the progress for requirements development and HFE evaluations was tracked through the TIP meetings. Future Plan: Have regular HFE input and attendance at all SDRP ERB, DR, and TIP meetings.

(37) Future Plans: Continue applying these processes and collaborations to future NASA missions in the 21st Century. Promote more standardized and integrated human factors processes and designs between KSC, MSFC, and JSC. Ensure that human factors engineering analysis remains an important part of the Engineering processes. Promote more collaboration with the ground support equipment, such as the flight and ground interface at the umbilical plates and the ground commodity connections to flight hardware.

(38) Future Plan: Introduce motion capture analysis into the tools for human factors engineering analysis, especially where a worksite analysis is needed or where two or more projects interface where multiple operators are required, Ares/Orion/GO [2]. See Figure-3. Motion capture allows for quicker and simpler and real to life simulations, and the computer models will include the CAD flight hardware and human Avatar which the envelope spaces between the human and flight hardware can be viewed, and the stresses to the human can be computed.

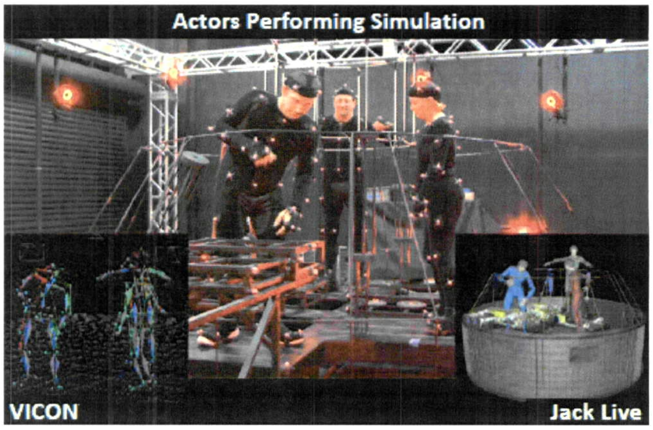

Figure 8

(39) Future Plan: Incorporate the timeline methodologies into the HFEAT [6].

(40) Future Plan: See how other FH tools such as the Relex HF module can benefit the human factors processes within design engineering. Currently the HFEA covers several aspects of Relax HF, so it may be possible to merge the two somehow into a software tool.

(41) Future Plan: Develop a Human Factors Engineering Plan and Roadmap.

8. CONCLUSION

There were great human factors progress made during this era and effort, development of HFEAT, and the HFEAs performed on the CxP GOP Subsystems, collaboration between CxP L2 to L3-GOP, and L3-GOP to L5 Design Engineering Directorate. Now that this has been accomplished, these efforts and collaborations will be continued and improved as NASA leads the nation and the world in future space endeavors and discoveries.

References

[1] Damon B. Stambolian, Scott Wilson, Kirk Logsdon, Darcy Miller, Jihan Dinally, Jason, Masse, and Tim Barth. "1-G Human Factors for Optimal Processing and Operability of Constellation Ground Systems" 2009 IEEEACpaper#1286

[2] Jeffrey S. Osterlund & Brad A. Lawrence. 61st Virtual Reality: Avatars in Human Spaceflight Training. International Astronautical Congress, Prague, CZ. Copyright ©2010 by the International Astronautical Federation. http://kave.ksc.nasa.gov/HEMAP/HEMAP2010/HEMAP2010.mp4

[3] Dr., Kanki, B,; Dr., Barth, T,; Ms, Miller, D,; Mr, King, J,; Mr., Stambolian, D,; Ms, Hawkins, J,; Mr, Westphal, J,; Ms, Dippolito, P; Mr, Dinally, J,; Ms, Blunt, M. " Human Factors Issues in the Design of Ground Systems: A Pathfinder Activity" http://www.congrex.nl/08a11/programme.asp

[4] Terry Greenfield, Don Young, Bill Tolson, Dennis R. Jenkins, and Elaine H. Williams. Kennedy Space Center Design Engineering Handbook - Best Practices for the Design and Development of Human Spaceflight Ground Systems. KSC-NE-9439. November 20, 2009. Page 77-79

[5] Damon B. Stambolian, Greg Dippolito, Bao Nguyen, Charles Dischinger, and Dr. Tim Barth. Human Factors Analysis to Improve the Processing of Ares-1 Launch Vehicle. 2011 IEEEACpaper#xxxx

[6] Damon B. Stambolian, Roland Schlierf, Juan Posada, , Darcy Miller, Doug Nelson, Mike Haddock, Mike Haddad and Dr. Barth, Tim. Human Factors Operability Timeline Analysis to Improve the Processing Flow of the Orion Spacecraft. 2011 IEEEACpaper#xxxx

[7] Foley, Tico and Stambolian, Damon B. "Human Factors Engineering; Acceptance, Implementation, and Verification as a System " NASA Lessons Learned 1801.2004. http://nen.nasa.gov/portal/site/llis/index.jsp?epi-content=LLKN_DOCUMENT_VIEWER&llknDocUrl=http%3A%2F%2Fnen.nasa.gov%2Fllis_content%2Fimported_content%2Flesson_1801.html&llknDocTitle=Lessons%20Learned%20Entry:%201801

[8] Stambolian, Damon B. "Human Engineering should be considered a Systems Engineering and Integration function" NASA Lessons Learned 1831. 2004. http://nen.nasa.gov/portal/site/llis/index.jsp?epi-content=LLKN_DOCUMENT_VIEWER&llknDocUrl=http%3A%2F%2Fnen.nasa.gov%2Fllis_content%2Fimported_content%2Flesson_1831.html&llknDocTitle=Lessons%20Learned%20Entry:%201831

Biography

Damon Stambolian *is currently working on a PhD in Industrial Engineering focusing his research on Biomechanics at the University of Miami's Biomechanics Laboratory. He is also currently working in the KSC Engineering Directorate at Kennedy Space Center. Prior to working in the Engineering Directorate he worked in; the Constellation Ground Operations Project office, the Space Station Program within the Orbiter Space Plane Project at KSC, and the Space Shuttle Program at KSC. Within these Programs he was involved with human factors related process improvements for ground processing operations, i.e., assembly, maintenance, inspection of flight hardware.*

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