Digital Human Modeling and Simulation for Virtual Ergonomics Evaluation
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Lecture – 19
Application of Digital Human Modeling and Simulation in various Industrial sectors Part II

In continuation to our earlier module that is module 7, where we discussed about application of digital human modeling software in agricultural sector. Now we are going to discuss this software application in aviation and aerospace industry.

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So, first we are discussing a review paper written by Sanjog et al 2015, the title of the paper - towards virtual ergonomics aviation and aerospace. So, in this review paper authors described, how various virtual ergonomics evaluation techniques has been used by various researchers all over the world, in aviation and aerospace industry Sanjog et al in the review, on application of virtual ergonomics in aviation and aerospace industries mentioned that DHM, technology has been used in assessing various human factor issues in those industries.

Those human factor issues include research and sorry reach and accessibility in aircraft cockpits, creating accurate posture libraries performing vision analysis, for pilots determining design modifications to accommodate female users, because many of the cockpits are initially designed for male users. Predicting probable pilot behavior in proposed cockpit design, simulating air flow and heat transfer in fighter planes cockpit, accessing comfort of airplane passenger seat, maintenance studies, human space flight training, verifying component accessibility and investigating impact of space suit parts and harnesses specific parts and harnesses etc.

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In this review paper, researchers described virtual ergonomics approach in aviation and aerospace industry with the following sub headings.

They discussed about how digital human modeling software can be used for cockpit, fight deck and crew workstation design. And also aircraft passenger seat comfort evaluations, they also mentioned regarding aviator musculoskeletal load fatigue due to protective equipment, design support in space station, maintenance application in aircraft and space station. So, with this following sub heading, authors actually categorize the available information in this fields, mean who are the various researcher what type of research they have conducted related to these topics.

So, that information has been categorized and represented here. Researchers presented critical review leading to a comprehensive knowledge body about application of digital human modeling in aviation and aerospace industry. They identified so, in this research paper following all these aspects of aviation aerospace industry. So, researchers also mentioned that which of the areas where other research can be carried out that avenues needed to be explored, and provided future research direction, aiming at aviation and aerospace completely human centric.

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So, in this review paper authors just compared the traditional ergonomic evolutional process, verses modern digital human model or CAD based evaluation method for ergonomic evaluation, in aerospace and aviation industry. Based on their comparison between these two, one is traditional ergonomic evaluation process.

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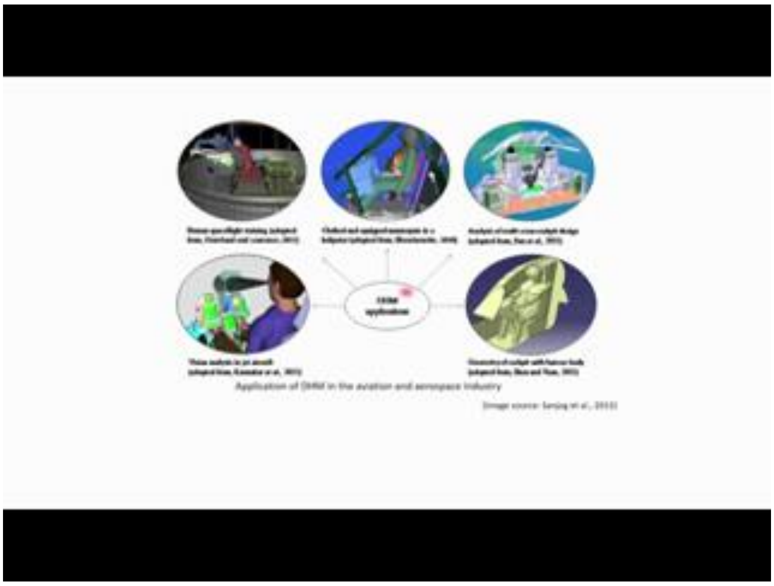

And next another is virtual ergonomic evaluation process using this data human modeling software in aviation aerospace industry. They concluded that the traditional approach for ergonomic investigations involving costly physical mockups and trials with real humans can easily be replaced by is effectively replaced by evaluations facilitated by digital mockups and digital humans. So, if you look at this image. So, in this image authors depicted the confidential ergonomic approach. So, how ergonomic approach been adopted for evaluation and various facilities and human factor issues in the aerospace industry aviation industry. So, they mentioned about few research paper. Laboratory setup with replicated aircraft flow and adjusted radiant, so this and this are provided.

Similarly pulling push pulling in a full size trolley in the laboratory, full motion helicopter simulated, simulator used for data collection trials. Then they also showed that ergonomic approach are also used for helmet configuration, with night vision goggles, battery power and counter weights .research pipes simulator being also be used. So, in this way through this image authors tried to demonstrate that various ergonomics aspects are being evaluated in aviation aerospace industry from the long back following traditional real human and real product based methods. But with the time CAD software came and now, most of this evaluation I mean performed in CADs virtual environment using data human being software and cat prototype of the view cabin or cockpit. So, these are the few examples, how various researchers have used the data human modeling software for their evaluation ergonomic evaluation of the cockpit or spacecraft.

So, first one human specified training. So, digital human body is used for specified training then clock and equipment manikin in a helicopter. Analysis of multi cube work station; when more than one cube is there then how they are interacting with each other and how they are resolving the conflicts in operations. So, all these are being studied then digital many researcher, have used digital human modeling software for comfort analysis vision analysis, in the cockpit or the aircraft. Similarly geometry of the cockpit and how human is interacting with the cockpit module that is also been studied by researchers.

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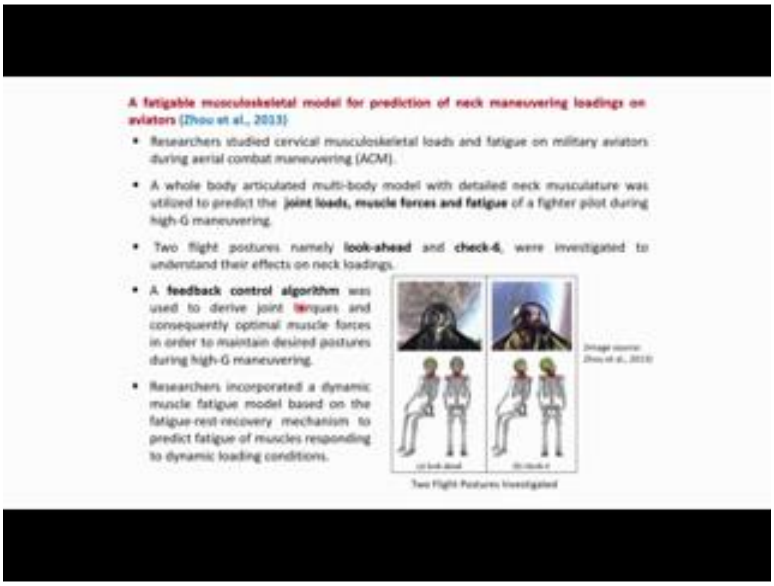

Now we are moving to the next research paper, this research paper is by Zhow et al 2013; title of this paper is a fatigable musculoskeletal model for prediction of neck maneuvering loadings on aviators, a fatigable musculoskeletal model for prediction of neck maneuvering loadings, on aviators. Researchers studied cervical musculoskeletal and fatigue on military aviators during aerial combat maneuvering. So, while this aerial combat maneuvering is being performed, then how is the cervical muscular musculoskeletal load and fatigue that has studied by these researchers Zhow et al 2013?

A whole body articulated multi body, model with detailed neck musculature was utilized to predict joint loads muscle forces and fatigue, of a fighter pilot during high g maneuvering. 2 flight postures named look ahead and check 6 are investigated to understand their effects on neck loadings. So, here it is shown in this image that 2 different postures which were assisting this particular research. So, one is look ahead while the pilot is looking forward and another is while the pilot is looking at an angle that is check 6 posture.

A feedback control algorithm was used to derive joint torques and consequently optimal muscle forces in order to maintain desired posture during high g maneuvering. Researchers incorporated a dynamic muscles fatigue model based on the fatigue rest recovery, mechanism to predict fatigue of muscles responding to dynamic loading conditions. So, while there is dynamic loading conditions high g maneuvering is going on, and there is change in the g value, then how their musculoskeletal load at the neck is being changed that was studied.

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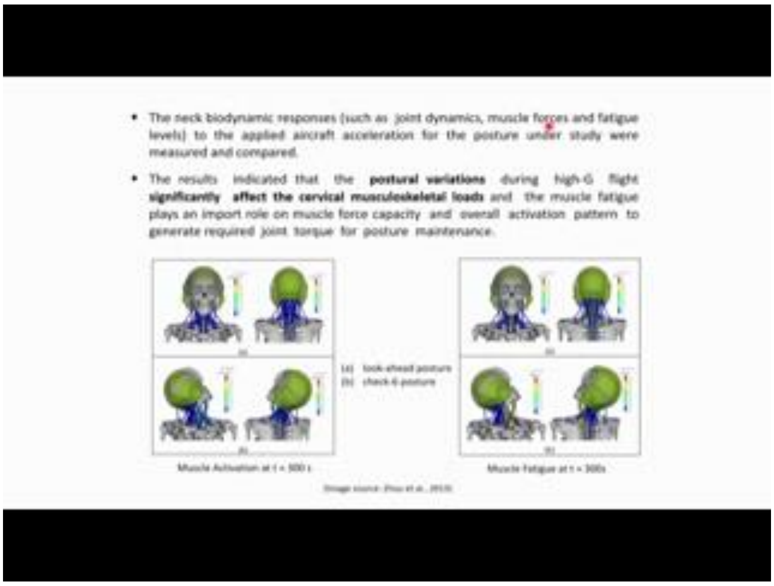

The neck biodynamic responses such as joint dynamics, muscle forces and fatigue levels to the applied aircraft acceleration for the posture under study were measured and compared, that whether there is any difference. Because two postures were studied, so between these two posture whether there is any difference in terms of neck biodynamic responses and also whether there is any change with a time.

The result indicated that the postural variations during high g fight significantly, affect the cervical musculoskeletal loads. And the muscle fatigue plays an important role on muscle force capacity and overall activation pattern to generate required joint torque, for posture maintenance. So, from these images, one is the upper one that is the looking ahead posture in both the panel. Similarly check 6 postures the bottom one check 6 posture. So, muscle activity at the beginning or starting time then this is the scenario in both the postures whereas, after 300 second how is the muscle activity muscle. How is the muscle fatigue? So, that is shown. So, due to this g force that as it is mentioned here the postural variation due to this 2 posture variation. So, you can see that muscle activity or activation level is defined. Similarly muscle file muscle fatigue is also different after a certain time.

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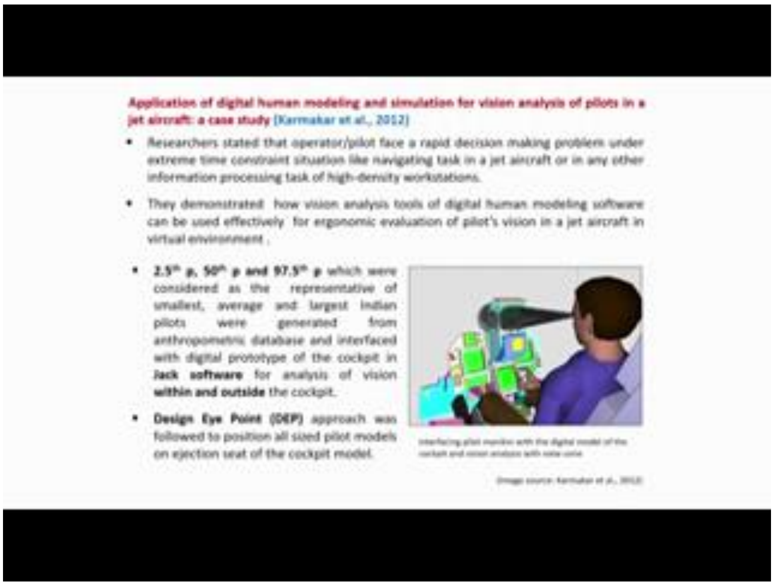

Next paper title is application of digital human modeling and simulation for vision analysis of pilots in a jet aircraft, of a case study. So, this was reported by Karmakar et al 2012. So, researcher stated that, the operator or pilot face a rapid decision making problem under extreme time constraint situation, like navigating task in a jet aircraft or in any other information processing task of high density workstations. So, in high density workstation, while pilot or operators are involved in processing made various information and the cognitive load is high. That time it is very important at least there should be reduced physical work load. Or we have to make the system in such way that work load should physical work load should be at minimum leave.

They remove the researchers demonstrated how vision analysis tools of digital human modeling software can be used effectively for ergonomic evaluation of pilots vision in a jet aircraft in virtual environment. For this purpose 2.5th percentile, 50 percentile and 97.5th percentile digital human models are created. These human models are actually representative of smallest average and largest Indian pilots. And those modules are inter-interfaced with the jet aircraft cockpit and various ergonomic evaluations are performed, by using jet software and the vision analysis within and outside the cockpit and assist. So, not only we inside the cockpit, but also outside the cockpit, you feel are also evaluated.

And for positioning digital human model on the ejection seat, design eye point approach was followed as it is mentioned here. So, deep in method was followed for positioning all sized pilot models in the seat. So, here it is showing that digital human model has been kept on the ejection seat, and that and various vision related evaluation is been performed. So, this is the analysis with youth.

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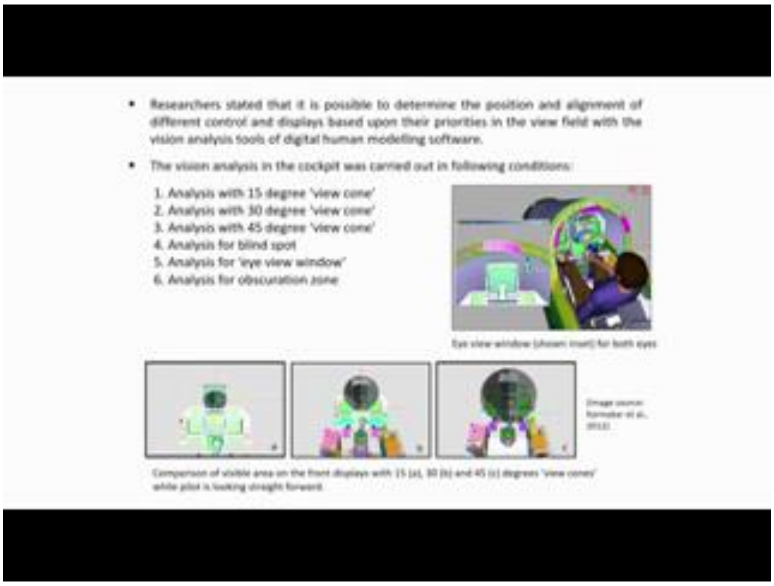

Researcher stated that it is possible to determine the position and alignment of different control, and displays based upon their priorities in the view field, with the vision analysis tools of digital human modeling software. The vision analysis in the cockpit was carried out in following condition

So, in this research paper researchers carried out. Visions of the pilot with this condition, with 15 degree view cone, then 30 degree view cone and 40 degree view cone, while there is variation in the size of view cone, the how the visibility is been changed or you feel the area of viewing field is changed. That has been that was studied analysis for blind spot, are also done analysis for eye view window and analysis for obscuration zone. So, if you look at the image. So, here it is shown. While vision is been analyzed with 15 degree view cone, then how much is the visibility of the free space. So, this is the display and on the display this portion is showing, within 15 degree view cone, how much area of the displays is visible to the pilots. Similarly while that view cone has been increased to 30 degree then the visibility increased and this much is covered, but to cover most of the displays actually pilot need a view cone of 45 degree. So, within 40 degree viewing angle pilot is actually able to see most of the displays facing in front.

Similarly, in this research, researchers also found that while the pilot is looking forward towards the display, then through eye view window this is the particular tool in that software with that tool, they identify that which areas is actually visible to the pilot. So, that is coming in a separate window this is that show in inside. So, while pilot is looking forward then this area of the above mirror and display that is actually shown in this area, vision analysis in virtual environment with digital human modeling software, has proved to very effective for positioning different displays.

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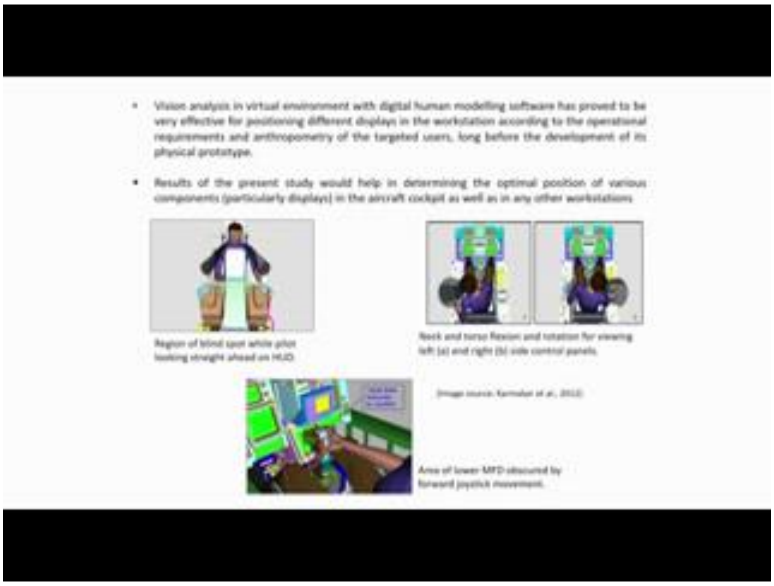

In the workstation according to the operators' requirements anthropometry and targeted users anthropometry of the targeted users, long before the development of actual prototype, so following this research, researchers mentioned that digital human modeling software is very effected in creating the finalizing the model of the CAD model of the cockpit, before actual because, the analysis is possible in virtual environment before developing the actual physical prototype.

Results of the present study would help in determining the optimal position of various components, particularly displays in the aircraft cockpit, as well has any other workstation. Similar vision analysis approach can also be adopted for other types of workstation. So, from this image which is visible that region of blind spot while the pilot is looking ahead of display. So, we can create this type of blind spot zone and it is from this particular result it is founded none of the display are coming within the blind spot area. So, displays are actually positioned properly.

Similarly while the pilot is looking on the side control panel, then how much is the neck angle, while the pilot is looking with 30 degree view cone on the side control panel, then that time body angle or torque angle neck angle. So, different body parts angle can be measured and we can identify how much difficulties are there to visualize, that side control panel. More over authors or researchers also demonstrated that how various displays are abstruse, due to various control operation like while the pilot is operating this throttle, due to position of the throttle this lower most control panel is actually abstruse. So, obtrusion zone toll of the digital human being software is very much effective for this type of study.

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Now, we are moving to the next paper, by Osterland and Lawrence in 2012. The title of the paper is application of digital human modeling and simulation for vision analysis of pilots in a jet aircraft, a case study. Researchers proved that the use of multiple object motion capture technology and digital human tools in aerospace is a more cost effective alternative, in comparison to developing costly physical prototypes. To provide a more efficient flexible and responsive environment, to change in the design and training and proactive consideration of human factors, concerning the operation of a complex launch vehicle or spacecraft, in this research papers, researchers demonstrated that how multiple object motion capture technology and digital human modeling software, can be used together for various for evaluating various ergonomics aspects, related to design training in the operation of complex launch vehicle or spacecraft. United Space Alliance USA developed the techniques and tools for virtual evaluation of both, spacecraft assembly, ground processing operation design, and training on the Orion crew module.

So, various parameters of interest and benefits of spaceflight simulation training with virtual reality, were mentioned by them and this is and here it is listed. So, it is good for familiarize, and access operational processes allows the ability to train virtually. So, from this system, it is possible to go for virtual training, of the crew or the astronaut experiment with what if, scenarios expedite immediate changes to validate the design implementation. It also possible in virtual environment to for going immediate changes and validates the design implementation.

3D animation of post training assessment, following the training from the recorded 3D video animation video, then it is possible to access that how was the training. Placement of aviators within 3D replicated work environment, in assembling processing in assembling or processing hardware. So, it is also possible to place aviators or manikin within 3D replicated environment, in assembling or processing hardware. Providing the evaluators, the ability to access task feasibility and identity potential support equipment, needed, providing human factors determinations such as reach visibility accessibility, so all these various aspects can be performed can be achieved by this system.

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The deployed system utilized 26 high speed high resolutions, vicon cameras. Maya animation software, jack ergonomic software, anark conversion, and polygon reduction software, 3D motion building software, integrated into 4 high speed 64 bit operating system platforms. So, this is the overall softwares and system description. To test the functionality of the laboratory and system 4 different test scenarios are demonstrated, and these are the 4 case studies, which they perform to test the functionality of the laboratory and the system. So, first one is Orion crew module environment - Orion crew module environment control and life support system installation and removal; second crew module seat removal and replacement. Third Orion service module drains port accessibility and visibility. Removal and installation of Orion crew module station power transfer unit. So, this are the 4 cases where they use they employed their deployed their system to find it is functionality and feasibility.

In CV 2010, United Space Alliance used augmented reality technology for human space activity, by adding a head mounted display to each actor. The system they found that the system would provide a level of human modeled simulation, not yet discovered, providing virtual reality to both the actor within the real environment and virtual reality of the integrated environment.

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If you look at the image, it is showing actors provide human in the loop simulated environment, Vicon cameras capture the stiff figures and jack live generate the aviators. So, inside this is the jack live software screen, and this is the CD motion analysis system. So, with the Vicon cameras based on the position of a marker, on the real human subject, the motion of the actors can be captured, and based on that motion captured motion jack live software can create the digital human model, and while these actors are performing their activity the same thing, the same action is being demonstrated by the human models, in the CAD environment and in that CAD environment while these digital human models are performing various activities then various ergonomics aspects create a related to their comfort related to the spinal compression force can be evaluated.

Actors performed here in this image it is shown, actors perform a (Refer Time: 26:08) to calculate the system prior to installation of the environment control and life support system unit through the crew module crew hatch. So, it is shown here. So, the real process or real function real activities performed by the actors, can be even various ergonomic aspects of their activities, can be evaluated in jack software it is possible because their activities are been simulated in virtual environment. And in virtual environment with the ergonomic evolution tool of the jack software is enabling to access various ergonomic accepts.

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So, in this image it is shown simulated reach operations and visibility with the specialized rubber suit called a self contained atmosphere protective ensemble suit provided inside into potentially required training. So, it is provided inside into potentially required training exercise. So, while it the it was simulated in the virtual environmental, while the astronaut or the crew members, are wearing this type of scrape space suit and that time or performing various activity, what type of difficulties , they are facing and accordingly, researchers realized that for this type of activities, actually the crew members or astronaut should be trained properly.

Similarly, while the real actor performing some activity in real scenario that is captured with the motion capture system. And the same is being transferred to the virtual environment of jack software. And from the jack software it is very easy for going different type of ergonomic evaluation, at the same time to identify potential problem, for this type of activity. If there is any problem related to safety or related to pollution or related to space requirement. So, all this aspects can be started in virtual environment. See in this image it is shown removal of a large surface area panel required, awkward positioning of the technician personal’s body, thus risking injury to themselves or the hardware.

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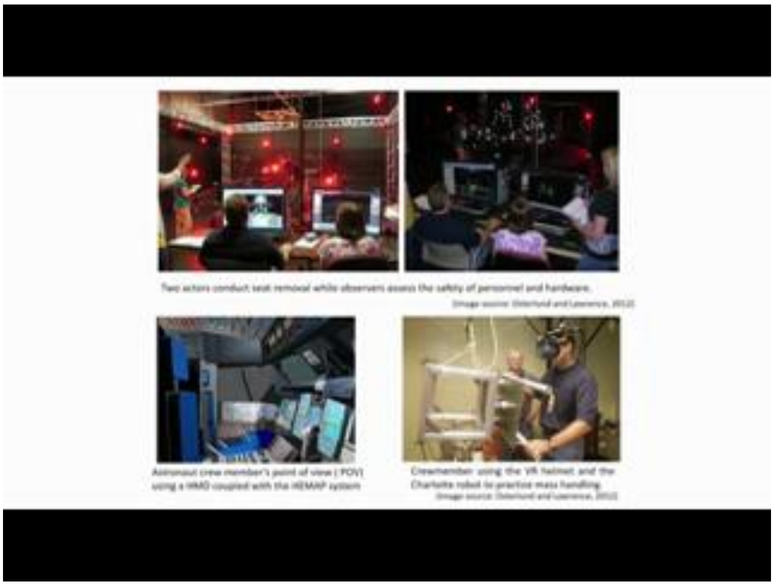

So, this 2 images indicating 2 actors, conduct a suit removal. So, 2 actors here in the real scenario, they are performing seat removal activity, while observers they are the observers assess the safety of the personal and hardware. So, while the real actor performing the activity is the same is being simulated on the computer screen, and the observer from the virtual simulation can understand can visualize, that what type of problem safety related problem, the personal can face during removal or assembly of the hardware, this image showing astronaut crew members point of view. While they are using head mounted display propelled with (Refer Time: 29:54) system.

So, in this image it is showing crew member using virtual reality helmet, and the (Refer Time: 30:00) robot to practice mass handling. So, why this type of head mounted display is there, at the same time the real operator is handling this type of robot, then the same information can be transferred to the virtual environment. So, the overall that system integrated this type of as you shown motion capture system, virtual simulation as well as virtual reality. So, these 3 teams they combine together for virtual evaluation of the space craft, or launch vehicle with this 4 case study as we mentioned earlier.

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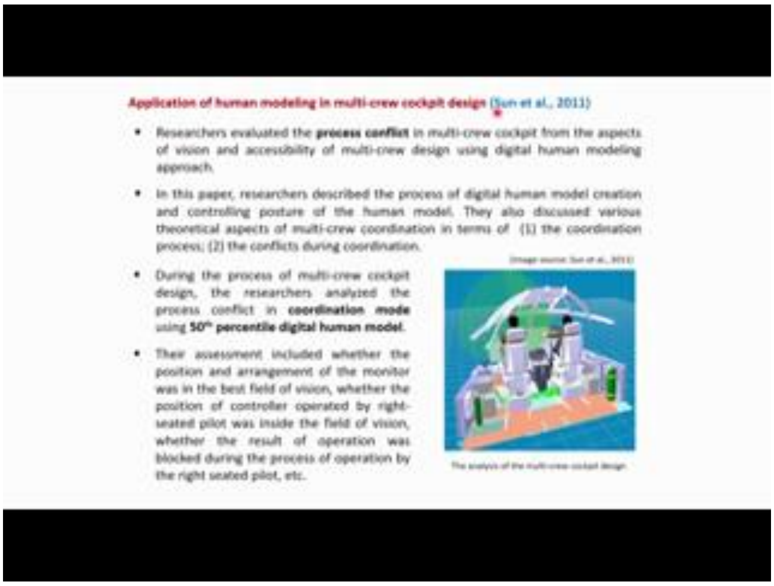

Now, we are moving to the next research paper, application of human modeling in multi crew cock pit design. This paper was written by Sun et al 2011. In this paper researchers evaluated the process conflict in multi crew cockpit from the aspects of vision and accessibility of multi crew design using digital human modeling approach. In this paper researchers described the process of digital human model creation, and controlling posture of the human model. They discussed various theoretical aspect of multi crew cockpit design, in terms of the coordination process, the conflicts during cooperation or coordination.

During the process of multi crew cockpit design, the researchers analyzed the process, conflict mainly they concentrated on process conflict. In coordination mode using 50th percentile digital human model, with 50th percentile digital human model, while they are evaluating the, multi crew cockpit design, they analyzed the process conflict in coordination mode. Their assessment include whether the position and arrangement of the monitor, was in the best field of vision, whether the position of the control controller operated by right seated pilot.

The pilot who is seated at the right side, this pilot while he is performing various controlling operation, was inside the field of vision, whether the position of the controller operated by the right seated person was inside the field of vision whether the result of operation was blocked during the process of operation by the right seated pilot. So, assessment include whether the position and arrangement of the monitor was in the best field of vision.

Similarly, while the right seater person is performing various activities, then the visibility of the left side pilot, whether it is being affected on that was also studied.

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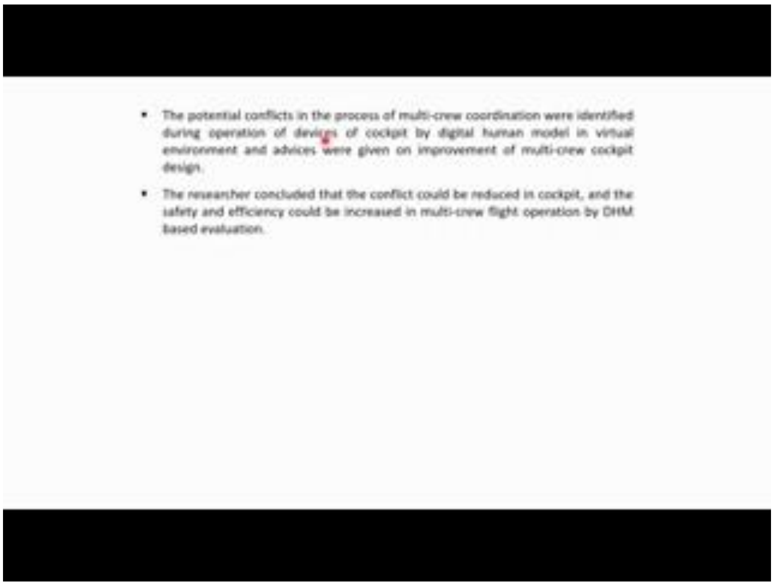

The potential conflicts in the process of multi crew coordination were identified during operation of devices of the cockpit by digital human model, in virtual environment. And advises are given on the improvement of multi crew, cockpit design. The researchers concluded that the conflict could be reduced in cockpit and the safety and efficiency could be increased in multi crew, flight operation by dh digital human based evaluation. Next research paper by Green and Hudson 2011, the title of the paper is a method for positioning digital human models in airplane passenger seat.

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So, this paper actually dealing with how digital human model can be positioned on the passenger seat. So, proper positioning of passenger manikin on digital passenger seat, is very crucial for evaluation of various human factor issues, related to seated passenger in a airplane cabin. So, the seated passengers need to perform various activities. First for example, operation switching the light or changing the seat rest angle, back rest angle and so many other activities.

Researchers developed a method for positioning digital human model in a digital passenger seat, based on their research on anthropometric and posture related requirements, along with establishing relationship. Between h point location which they have mentioned as digital human model seat reference point with seat seas seat reference points, they establishing the how the position the digital human model, the position the digital human model, based on the relationship of h point location of the digital human model or SRP location, of the digital human model with seats SRP.

They claimed that the standard passenger postures, identified in this paper, are more accurate than the eye ball method and simple to implement. So, for this purpose 26 subjects were selected for whole body scanning, based on their anthropometric similarity, to idealized 95th percentile boundary manikin groups, to ensure a large variability of the targeted user group. So, they identified 26 subjects and took their body scanning because those persons are similar to idealized 95th percentile boundary manikin groups. And this selection process actually ensures a large variability of the targeted user group. So, they scanned the body dimension of 26 passengers, while they are seated on the passenger seat. The subjects were scanned in various postures from seated erect to slightly slump. The seated erect posture was used for the development of standard posture of the passengers. So, out of various types of postures, selected postures finally, the seated erect posture was used for developmental of the standard passenger postures.

Additional anthropometric data, collected by faro 3D digitizing arm, was used for direct point to point measurement among anthropometric landmarks and with land marks on the seat. This data was used to determine the relationship of the subjects to the seat.

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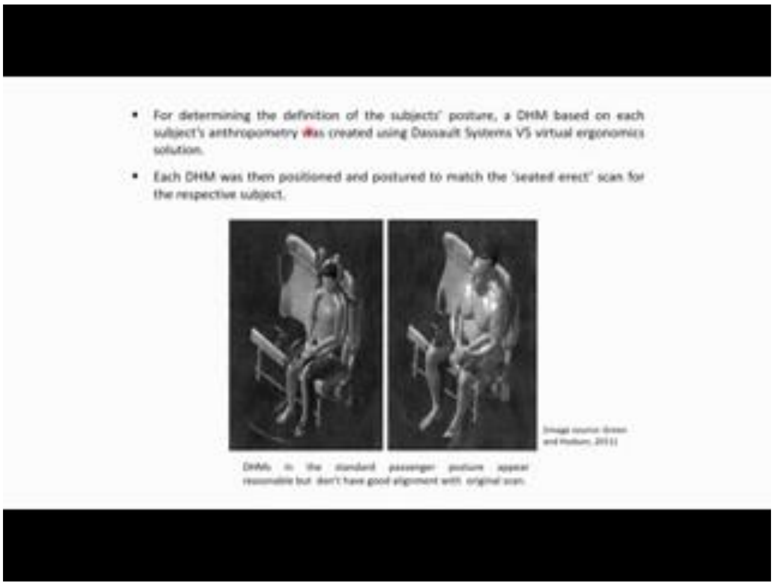

For determining the definition of the subjects posture a digital human model on each subjects anthropometry was created using Dassault Systemes v5 virtual ergonomics solution. So, they used digital human modeling software, that is the Dassault Systemes v5 human to provide the subjects posture. Each digital human model was then positioned and postured to match the erect scan of the respective subject. So, on the erect scan of the respective subject of the passenger - first what they did they created the digital human model based on the anthropometric of the passenger, then superimposed the digital human model on the scan, 3 body scan image of the same subject or the same person. After the super imposing, super imposing of the digital human model on the scanned image, it was found digital human model in the standard passenger postures, appeared reasonable, but do not have good alignment with original scan.

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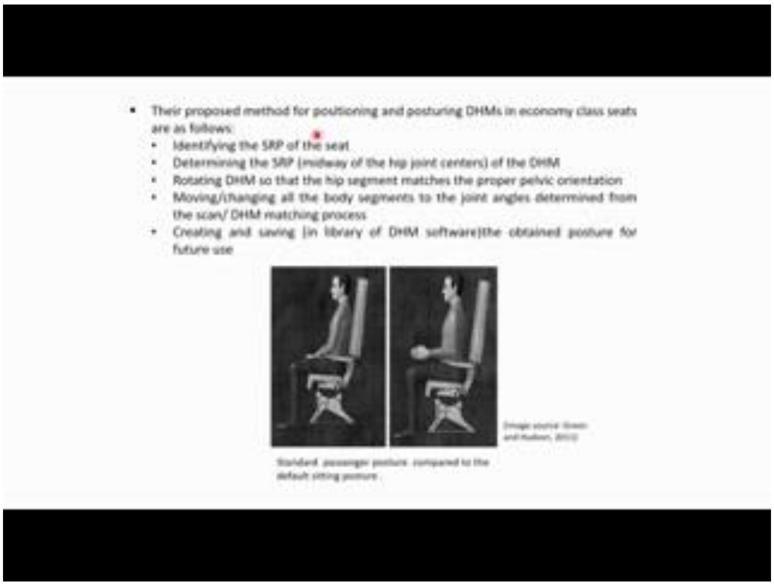

Their proposed method for positioning and posturing digital human models in economy class seats are as follows. So, first identifying the SRP seat reference point of the seat, determining the seat reference point that is the middle of the hip joint point or reach point of the digital human model, SRP of the seat SRP of the human model and these SRP of the human model is the reach point of the human model third rotating the digital human model. So, that the hip segment matches the proper pelvic orientation with the scanned image. Moving and changing all other body segments to the joint angles determined from the scan or digital human modeling process.

Creating and saving the final posture adapted by the digital human model, and save it to digital human models library. For further use if you look at this image. So, why normal erect posture is provided by digital human modeling software, then the scenario is like this. So, it is not exactly matching with the seat passenger seat, but the method which has been described in this research paper, if you follow that paper than the standard posture is it is actually matching with the seat profile. So, with this method designer or engineer can easily provide appropriate seating posture to the digital human model, while they are interfacing the digital human model with the passenger seat.

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Next we are going to discuss one more research paper related to passenger's seat only. So, this research paper is related the title is, on the creation of 3D libraries of F 16 pilots, in their crew station. Method development library creation and validation, this was reported by (Refer Time: 40:41) et al 2011. The reported research was aimed to develop a posture library for safe work digital human model system. So, this research was actually aimed to develop a posture library for this particular digital human modeling software named safe work. To reduce the errors related to initial positioning and posturing of the manikin. Because if initial positioning and posturing of the manikins on the seat is not proper, then the whole ergonomic evaluation in the F 16 pilot cockpit will be, will be meaningless or useless.

So, for that purpose proper positioning of the pilot, in the cockpit in the seat ejection seat is very important. The proposed method for providing posture to digital human model enables the manikin to assume realistic posture by employing 3D body scan. To real people in F 16 ejection seat as we mentioned in the earlier paper also. So, digital human model actually provided realistic posture by employing 3D body scan, of the real pilot or real subjects' posture library was developed for initial position and posture, during reach as well as to quantity the effect of restraint system and protective equipment, in F 16 cockpit environment.

14 subjects from both sexes male female, and wide range of anthropometric shape and proportion variation, were considered in this research. These 14 subjects participated in the creation of F 16 safe work posture library. The posture library development followed these following steps; so first scanning of the subjects in F 16 ejection seat to record position and posture data. Next creation of safe work manikins based on subject anthropometry. So, first body scanning, second safe work manikin creation based on the subjects anthropometric data. And third is this digital human model has to be aligned with the scanned image of the person. So, align manikin to scan creation of safe work posture library.

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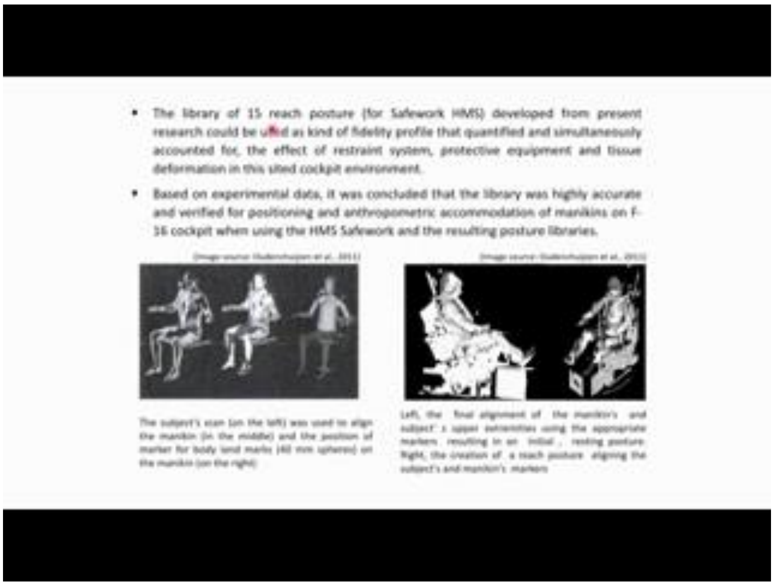

The library of 15 reach postures, for safe-work human modeling system developed from the present research, could be used as a kind of fidelity profile that quantified and simultaneously, accounted for the effect of restraint system protective equipment, and tissue deformation in the sighted cockpit environment, that is F 16 cockpit environments.

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So, these are the 15 postures which we were discussing. So, the 15 resulting postures of the library of each small manikin are the combination of the 3 heights. So, they are reaching at 3 different heights at the top and in 5 directions. So, this is shown from these top images. These top 5 images are actually indicating the 5 reach direction. Similarly the top 3 images is showing the, this side image is showing the reach in various heights. So, this 15 reach postures are actually, developed out of this research. And this are this type could be used as kind of fidelity profile that quantified and simultaneously, accounted for the effective effect of restraint system, protective equipment and tissue deformation.

Based on the experimental data, it was concluded that the library was highly accurate and verified for positioning an anthropometric accommodation of manikins on F 16 cockpit. When using human modeling system safe work and the resulting posture libraries. So, here it is showing that how that digital human model is created and positioned on the seat. So, first scan image or body scanning data of the real pilot then on that, body scan image digital human model is positioned and this is the final digital human modeling posture. So, on the scanned image digital human model is superimposed and posture was given and this is the final posture.

Similarly in this image left the final alignment of the manikins and subjects upper estimate is using appropriate markers, resulting in an initial resting posture. So, left side is the initial resting posture and right side this image is showing the creation of a, reach posture aligning the subjects and manikins markers. So, how this posture can be this particular reach posture can be achieved. It can be achieved by aligning the subjects and manikin markers. So, around the many subjects this scanned image, there are markers those markers and the corresponding markers around the human model can be manipulated to achieve a particular posture. So, this image already we discussed.

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Next this is actually a next we are going to discuss about the technical report by us army research laboratory and it is reported by (Refer Time 46:54) et al 2010. So, title of this technical report, was mentioned as overview an overview of human fatigue modeling, sorry human figure modeling, for army aviation system. So, in this technical report actually, researchers described various human modeling systems, which have been used for army aviation system in US army research laboratory. Following the extensive review on application of digital human model in army aviation system by US army research laboratory Hicks et al 2010 stated that, digital human model software's or digital human model software's has been used to access, and improve the ergonomic design, and usability of all modernized army aviation system, as well as to reduce analysis and development time lines.

Army research laboratory human research and engineering director, known has ARL-HRED has developed a digital library of army aviation aircraft and equipment, to access them in terms of human factors engineering design standards. So, they developed the library for army aviation aircraft as well as various equipment and those can be to assess them in terms of human factors issues. The modeling conducted by that laboratory has resulted in numerous system design improvements to meet the human factors engineering, design standards. In the report researchers mentioned that modeling results have been used by government and industry to improve the ergonomic design and system functionality. Access anthropometric requirements and reduce analysis timelines.

The report described that use of digital human model design and development of various aviation system including. So, this is the least including various aviation systems (Refer Time: 49:17). So, they actually covered it aviation system which are UAE 60 m black hawk CH 47 D Chinook, armed recognizance, helicopter RAH 66 Comanche, army airborne command and control system, air warrior advanced threat infrared counter measure system common missile warning system for 64 D.

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So, digital human modeling software jack has been used by ARL-HRED in the development and testing of 8 army aviation system as we mentioned earlier.

To access and improve the ergonomic design and system capabilities, so if you look at this particular table. Then you can find these are the list of 8 workstations where various ergonomic aspects, are evaluated using digital human modeling software. In the first one RAH 66 Comanche, researcher studied investigate analysis crew station design review mirror location, helmet integrated display, sight system and so, it helmet integrated display sight system analysis, the next workstation 60 m Blackhawk researcher studied crew station design, anthropometric design analysis, and the third workstation the design they evaluated (Refer Time: 50:57) analysis in case of air warrior anthropometric design analysis was performed in common missile warning system, AE 64 CMWS, sense of field of view was evaluated, then advanced threat infrared counter measure in this, in this case maintenance analysis were was performed, the next armed recognizance helicopter trans-portability analysis, anthropometric design analysis was done, that in case of Chinook anthropometric design analysis was performed.

So, in various types of workstation researcher various researchers performed different types of ergonomic or human factor issues, using digital human modeling software in various times. So, all these research actually carried out in ARL US Army Research Laboratory.

So, among these various workstations; the next 2 slides we will discuss only on RAH 66 Comanche and these few analysis will be discussed.

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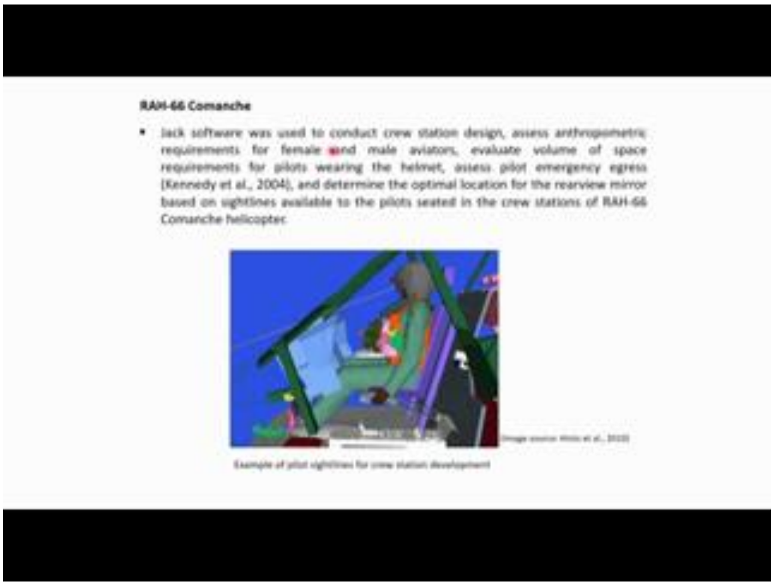

So, jack software was used to conduct crew station design, assess anthropometric requirement for female and male aviators, evaluate volume of space requirements for pilots, wearing the helmet, and assess pilot's emergency egress. So, this was actually reported by Kennedy et al in 2004. So, for detailed information this particular research paper can be studied further. And determine the optimal location of the rearview mirror based on sight lines available to the pilot seated in crew station of RAH 66 Comanche helicopter. So, this various ergonomics aspects are evaluated in RAH 66 Comanche helicopter. So, in this particular image, it is shown that how line of sight in relation to display position has been evaluated in Comanche crew station.

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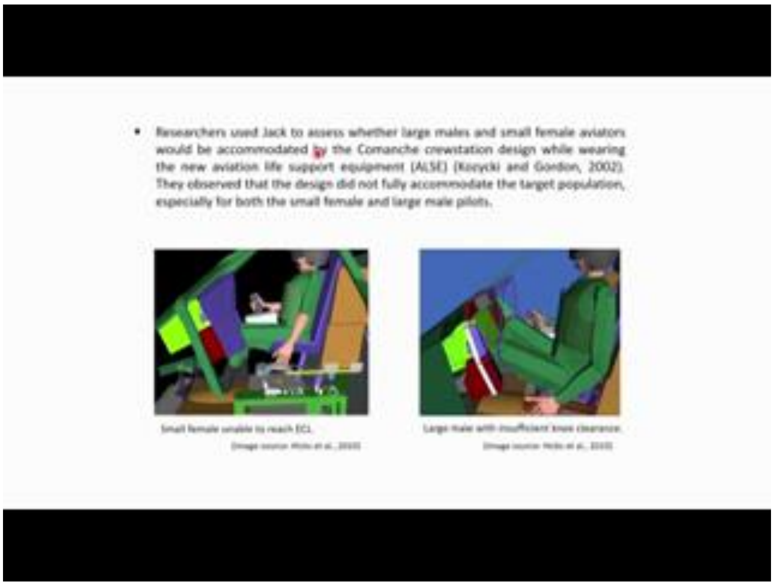

Researchers used the jack to assess whether large males and small female aviator would be accommodated by the Comanche crew work station design. While wearing new aviation life supports equipment. So, this was actually reported by (Refer Time: 53:51) and Gordon in 2002. They observed that design did not fully accommodate the target population especially for both the testing that is the small female as well as for large male pilots, so small female unable to reach ECL; so here it is shown that the small female it is difficult to reach the ECL. On the other hand while the large male with insufficient knee clearance; they do not have sufficient knee clearance below the display panels. So, for both the estimate esteem population that is the smaller female as well as larger male pilots they are finding difficulties.

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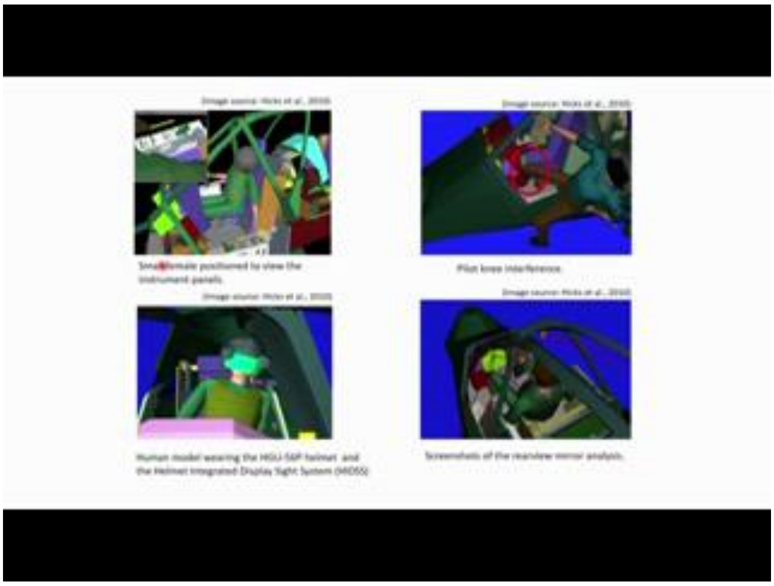

In this image, it is shown, small female positioned to view the instrument panels. Pilot knee in inference interference, while pilot is coming out their knee is touching with the display panel. Similarly while human model wearing HGU 56 P helmet and the helmet integrated display sight system. Then if there is any problem in their performing the activities or in relation to (Refer Time: 55:19) that was studied.

Similarly, while pilot is seated on the seat. Then through the rear view mirrors which area is visible, that was also studied in Comanche crew work station. So, various ergonomics aspects, had studied down the years. And it was reported by various researchers and all this research were carried out in army research laboratory USA. We have discussed various in various research paper that how digital human modeling software, was used for evaluation of air cockpit or passenger seat or spacecraft and that is also important digital human modeling software is also has been used in combination with virtual reality 3D motion analysis system. And these approaches are found to be very effective for, not only ergonomic evaluation purpose also called training purpose. Then identifying various problems during maneuverability during (Refer Time: 56:32).

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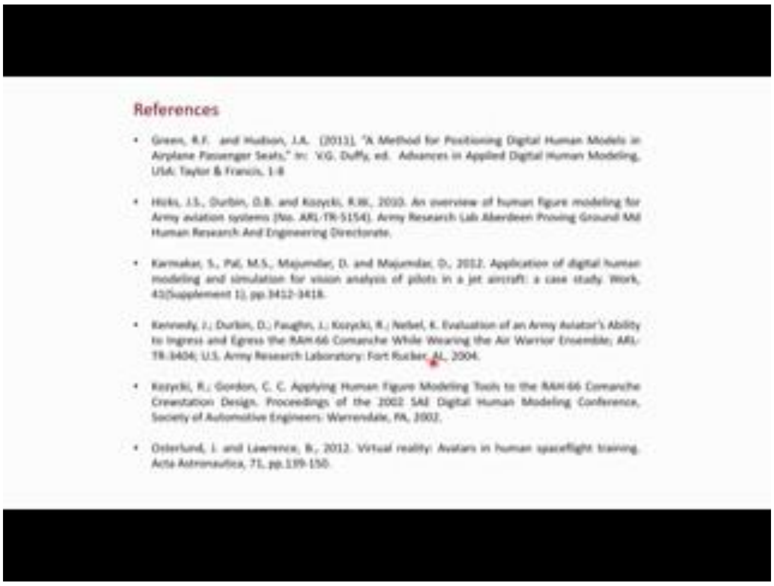

So, these are the references which have been differed in various slides.

Thank you.