Integrated Use of 3D Modelling tools and Virtual Reality to facilitate Design

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Synopsis

The technologies of: Anthropometric Modelling, Game Engine animation and Virtual Reality were integrated to facilitate early design decisions in the design of future Naval weapon systems and their integration into current and future Naval platforms. CAD Models of existing or future ships were imported into a 3D Games engine (Unity) along with CAD Models from the ship architect/designer of specific compartments where weapon system installations were proposed. Extremes of the user population (e.g. 3rd percentile Navy female and 97th percentile Navy male) were modelled performing the installation / maintenance tasks on the equipment and this was then exported/imported into the 3D Unity environment and viewed from predefined eye height perspectives. Within the Unity 3D environment, realistic dynamic aspects of the real world were added – e.g. ship movement in light or heavy seas as well as consequent human head / body movement (compensating for ship movement) and the effects that this may have on the task. In addition weather and visibility effects can be added which may affect the user's ability to perform the tasks. Design engineers viewing the model in VR were able to get a sense of the distances / gaps / access from within the 3D model itself and make/feedback design recommendations from the unique perspective of being immersed within the design itself.

Keywords: Human Factors; Virtual Reality; Games Engine; Modelling; Design; Integration; Marine systems

1. Introduction:

Recent developments in the Gaming Industry and Virtual Reality technology have opened up new opportunities to help 'do' and 'validate' designs of equipment to install on Naval platforms. Currently, Human Factors analysis is conducted using an Industry standard anthropometric tool called JACK. [1]. This enables import of CAD Models (in JT format) and the creation of detailed appropriately scaled human models. These models can then be positioned in the postures required to complete the assigned tasks with the designed equipment. From this detailed analysis measurements can be taken and constraints obtained to feed back to design engineers to either re-design equipment or restrict the user population to specified sizes or provide other mitigations to ensure that the task can be completed using the designed equipment. This method provides an adequate analysis to aid design decisions and provide necessary evidence to fulfil the requirements.

However new software and technologies have become available which can supplement this detailed analysis method with immediate environment effects, animation, and an opportunity to place the viewer inside or beside the equipment to help them better appreciate the proposed design solution and get a different perspective on any potential design issues or hazards, not immediately obvious from only looking at a JACK model on a 2D screen.

Thus the existing analysis was combined with two other technologies – a games engine (UNITY) [2] and a method of viewing the developed model in Virtual Reality (Vive) [3] in order to provide this additional appreciation of the proposed design.

Thus the combined use of the following tools was assessed:

- JACK (3D anthropometric modelling tool [a Siemens Tool])
- Unity (3D Games Engine)
- HTC Vive (Virtual Reality Headset and Hand Controllers).

2. Existing Method

2.1. JACK

JACK is a 3D anthropometric modelling tool used to create and adjust human models of various sizes into the required postures to carry out the tasks required. It is possible to perform rudimentary 'force' assessments and also simple animation (moving human figures from one place to another). Its use is primarily to determine what size (of relevant anthropometric measurement) of personnel can reach and access the installed designed

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equipment. Figure which shows a Console example along with the operator's field of view (Eye-cones) and actual view (inset).

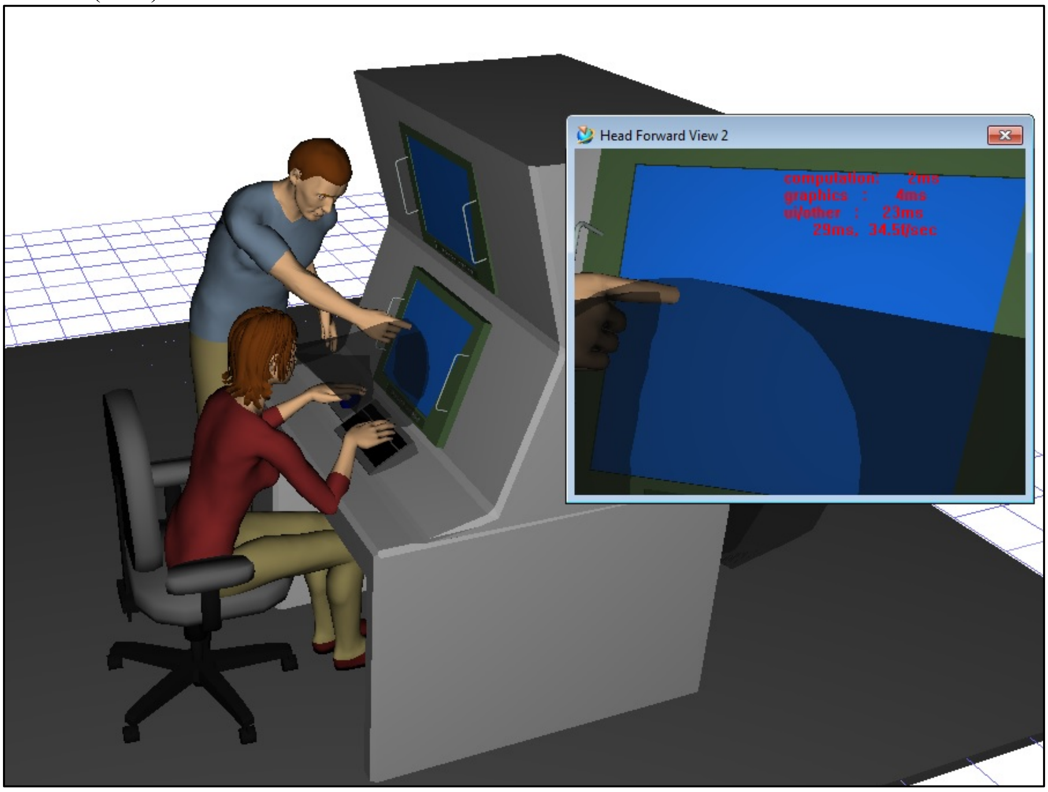

Figure 1: Analysis using JACK Anthropometric Modelling Tool

Typically the Human Factors team analyse and contribute Human Factors evidence to meet an overall requirement.

The Human factors requirements usually specify extreme sizes of the user population that should be capable of performing the task (e.g. 5^{th} percentile female to 95^{th} percentile male), with the assumption that if these two extremes can perform the task, then the rest of the user population (in between these two ranges) should also be capable of performing the task

Proposed equipment models are created and designed equipment converted and imported into JACK. Human models of each extreme size (e.g. 5^{th} percentile to 95^{th} percentile) are then adjusted into the appropriate postures of the worst case tasks (e.g. Reach or Access tasks). An analysis is then conducted to determine what range of the user population should be capable of performing the task.

Initial analysis is then fed back to design engineers to influence their final design. This may be an iterative process which eventually arrives at a final equipment design. This final equipment is then imported into JACK and the human models postured and positioned to gather 'evidence' in the form of 'snapshots' showing the human extreme sized models performing the task (see Figure 2).

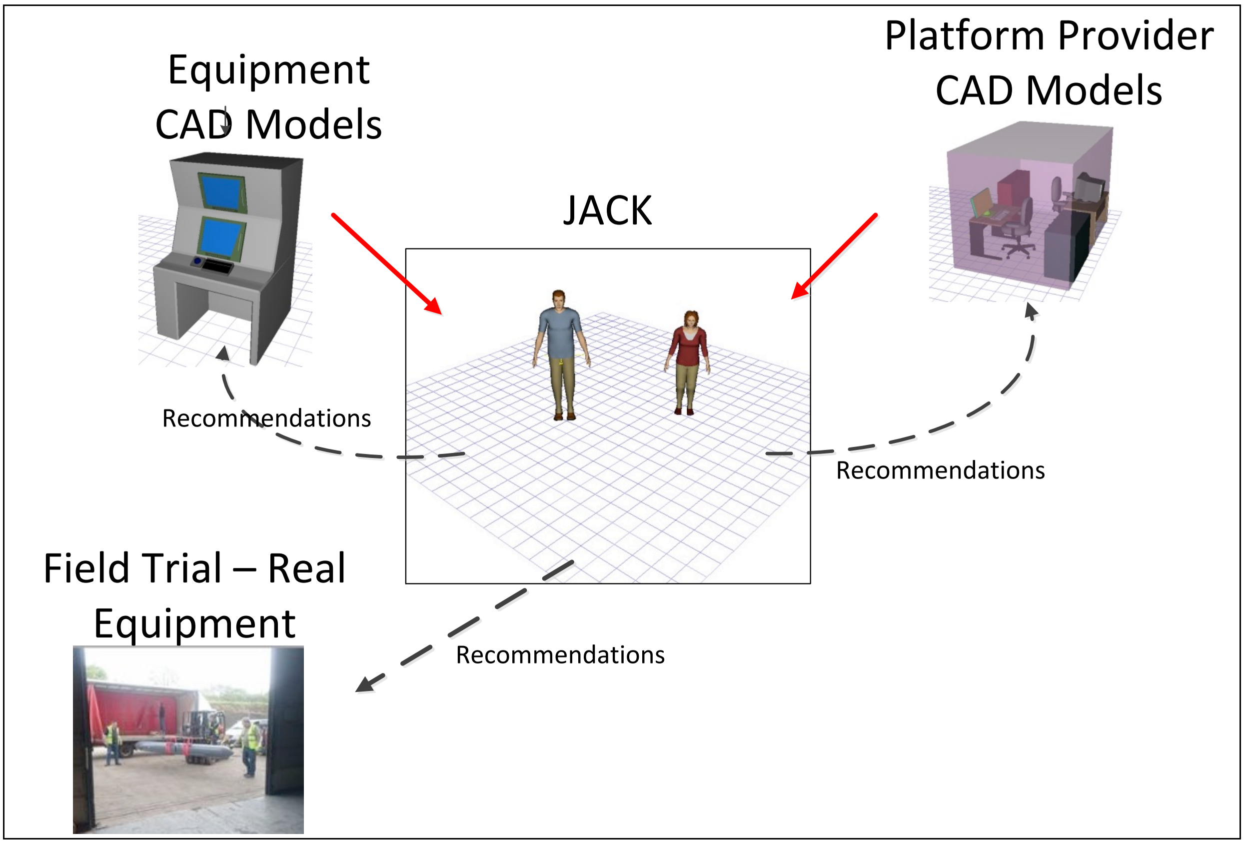

Figure 2 Existing Human Factors Assessment / Evidence Gathering

3. Current method shortcomings

Although exact measurements can be taken in JACK and viewpoints taken from the models, there are a number of aspects of the task and its immediate environment that can't be adequately catered for using JACK.

3.1. Realistic Lighting

Lighting levels within the JACK modelling tool can be set, but are quite primitive and don't approximate to for example environmental lighting effects of weather (rain or fog) or night / starlight conditions..

3.2. Dynamic aspects of the immediate environment (e.g. moving ship)

Very rarely is environmental movement taken into account when assessing humans performing tasks (even in part-task real world mock-ups). However in certain environments, movement is an integral component of the immediate task environment. The maritime environment is such a case due to wave induced motion. In the land domain movement from vehicular travel is also a major consideration, (if a task needs to be performed in-transit). In the maritime environment the 'sea state' will affect whether or not a task can be performed and the ability of the operator to perform it. Thus aside from the ship moving and the human body moving in reaction in order to maintain balance, the visual system will be affected – ability to legibly read displays and reports will be affected, and the degree of effective movement will depend on a number of factors including sea-state level, ship speed, ship aspect, wind, size and mass of ship and where on the ship the person is located.

4. Modifications to Method

Games Engines enable the creation or import of 3D Models and animation and lighting effects bringing added realism (of the real world). Sound effects can also be added and coded to commence on some specified event trigger. Physics, gravity and collision can also be included to simulate real word solid surfaces interacting with each other. Primarily these 'Games Engines' are used to build games, however they can also facilitate the creation of animated simulated environments.

The missing elements of the existing method (highlighted above) can be incorporated by importing the models into a gaming tool such as 'Unity' and then viewed from within using VR technology such as HTC Vive

[3]. Note, other similar technologies could also have been used – such as ‘UNREAL’ games engine and ‘Oculus’ VR headset.

4.1. Games Engine (UNITY)

Unity is a cross-platform real-time engine developed by Unity Technologies. Unity gives users the ability to create games and interactive experiences in both 2D and 3D, and the engine offers a primary scripting API in C#, for both the Unity editor in the form of plugins, and games themselves, as well as drag and drop functionality. CAD models converted into the appropriate format (.FBX, .OBJ etc.) can easily be imported, positioned, scaled and animated within this environment (see Figure 3). In addition weather effects and terrain maps can be imported for added realism and lighting can be finely tuned. Audio effects can be added to occur at specific times or event triggers, and pre-rigged characters with associated animations can be downloaded and incorporated into the design ‘scene’.

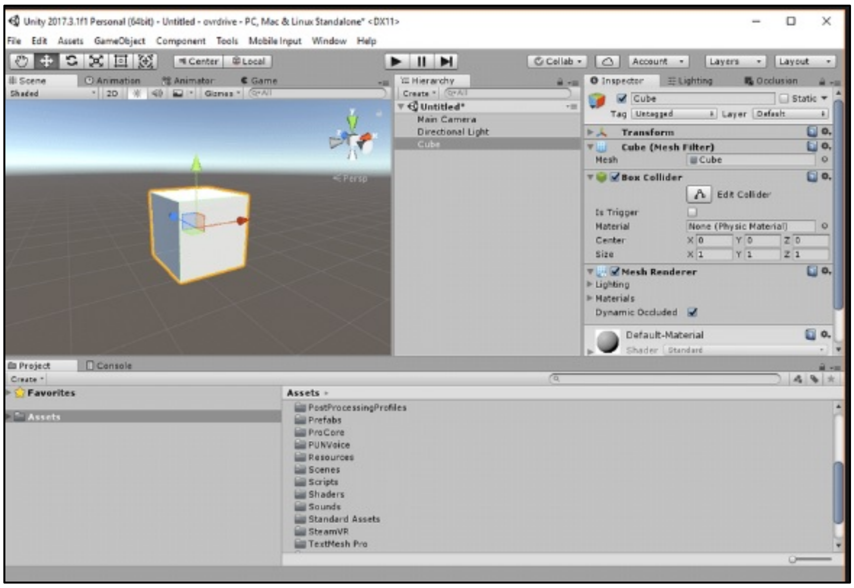

Figure 3 The UNITY Games Engine User Interface

4.2. VR Headset (HTC Vive)

The HTC Vive is a virtual reality headset developed by HTC and Valve Corporation. The headset uses "room scale" tracking technology, allowing the user to move in 3D space and use motion-tracked handheld controllers to interact with the environment (see Figure 4).

Figure 4: Vive VR Headset and handsets

5. Integration Method

The integration method employed involved the following steps (see Figure 5).

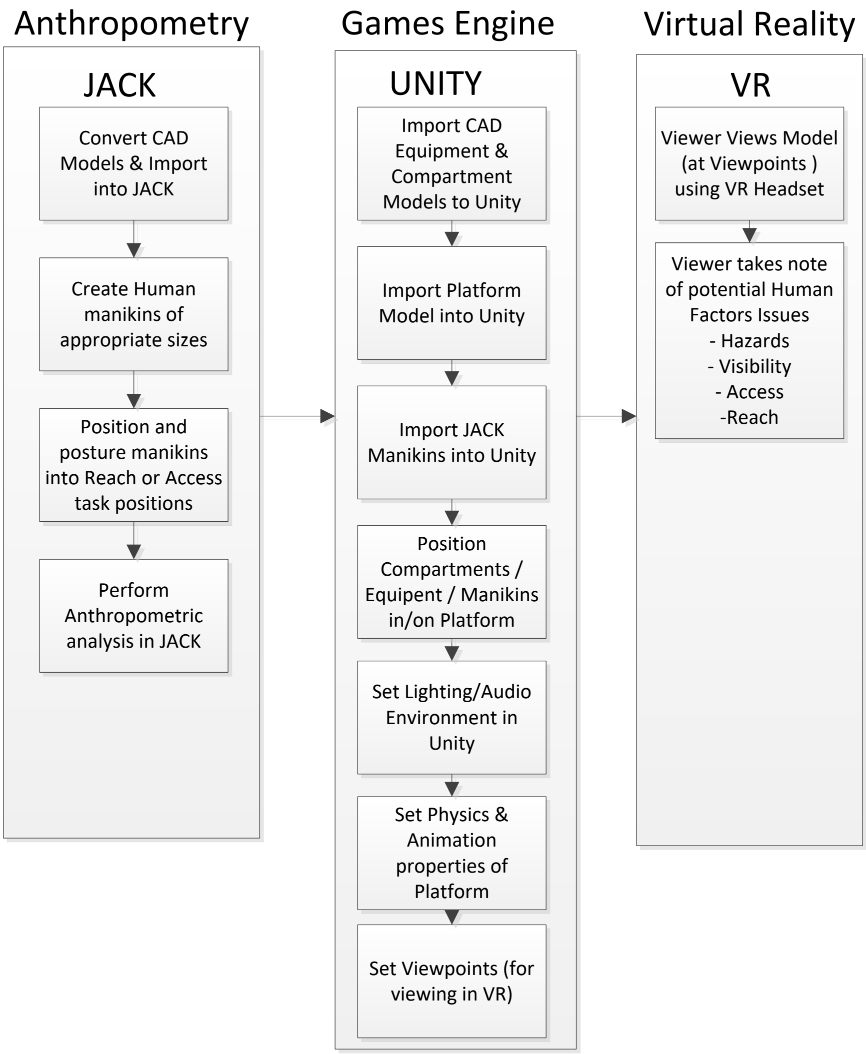

Figure 5 Integration of the use of the three tools

The anthropometry analysis was performed in JACK (as per method 1). Then this 'Integration Method' integrated the CAD Models from Mechanical Engineers, third party platform providers (compartments etc.), and positioned them in the appropriate locations on the platform – in this case a ship (Public domain 'Shell') alongside appropriately scaled anthropometric 'Human Manikins' from JACK, as shown in Figure 6. Within Unity, physics, animation and lighting effects were added and viewing positions (Cameras) were setup to facilitate viewing the model within VR.

Design engineers put on the VR Headset (and held controllers if required) and immersed themselves in whatever part of the design they were interested in. There was 'limited' movement of about 1 metre in all directions enabling them to look down/up/under etc. to check clearances. They were also 'positioned' at the exact eye height of for example a 5th percentile female to determine what she can see from her position. The hand controllers were used to emulate 'virtual hands' These 'virtual hands' could be used within the VR environment to observe potential reach and access issues relating to the equipment. Any potential issues could then be recorded and investigated further either using JACK, or part-task trials and physical mock-ups.

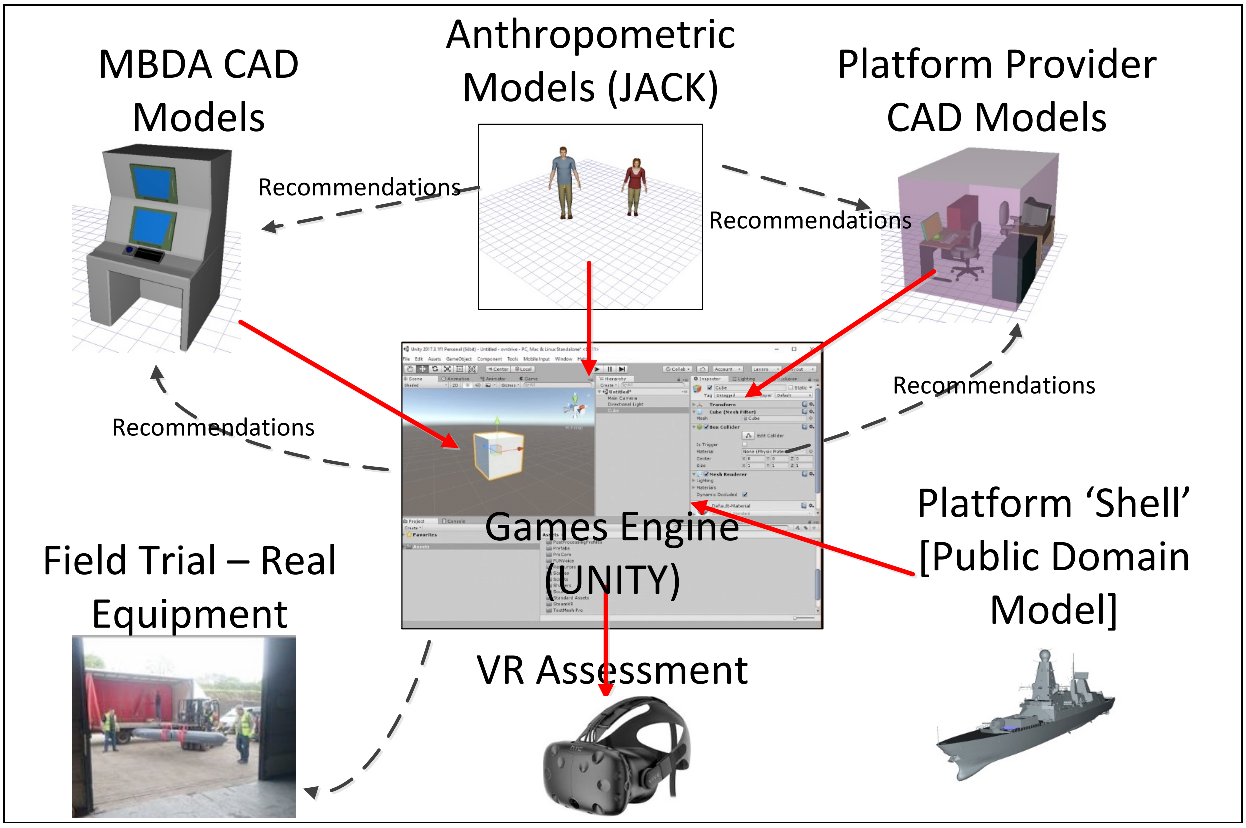

Figure 6 Integration Method

6. Results

A few examples are given below of a few of the tasks assessed. A subjective assessment is then given alongside some feedback from an Engineer using the system.

6.1. Reading displays in rough seas.

In this example, the 'viewer' is stood on a moving deck (and consequent head motion) in rough seas and attempted to read the labels on a control panel mounted in front of them (see Figure 7). The image shows the view from the viewer's perspective. Other 'animated' characters were later added to the scene to test import of animated 'rigged' characters. These could in future be 'animated' crew performing their daily tasks.

Figure 7 Reading a control panel in rough seas (other animated characters added to scene) – Control Panel Photo Credit Jonathan H. Ward

6.2. Reaching Equipment Parts

In this example a user reached out with ‘Virtual hands’ (VR handsets) to see where they could reach to on certain parts of installed equipment (see Figure 8).

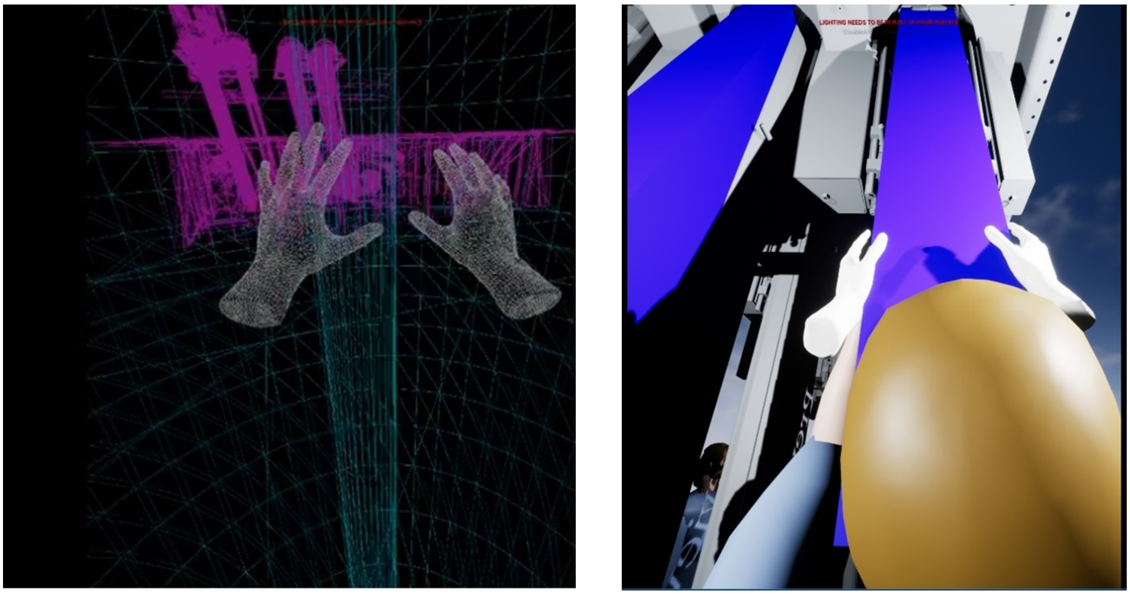

Figure 8 Virtual hands reaching equipment parts

6.3. Assessing walkway width

In this example a user was positioned inside a missile silo such that they could be completely immersed within the equipment design and assess different aspects of it. In the example shown in Figure 9 the design engineer was 'immersed' within the silo and from this perspective it became apparent that the walkway width (indicated in red) was too narrow and needed to be widened to prevent a large male (97^{th} percentile) potentially falling off the walkway.

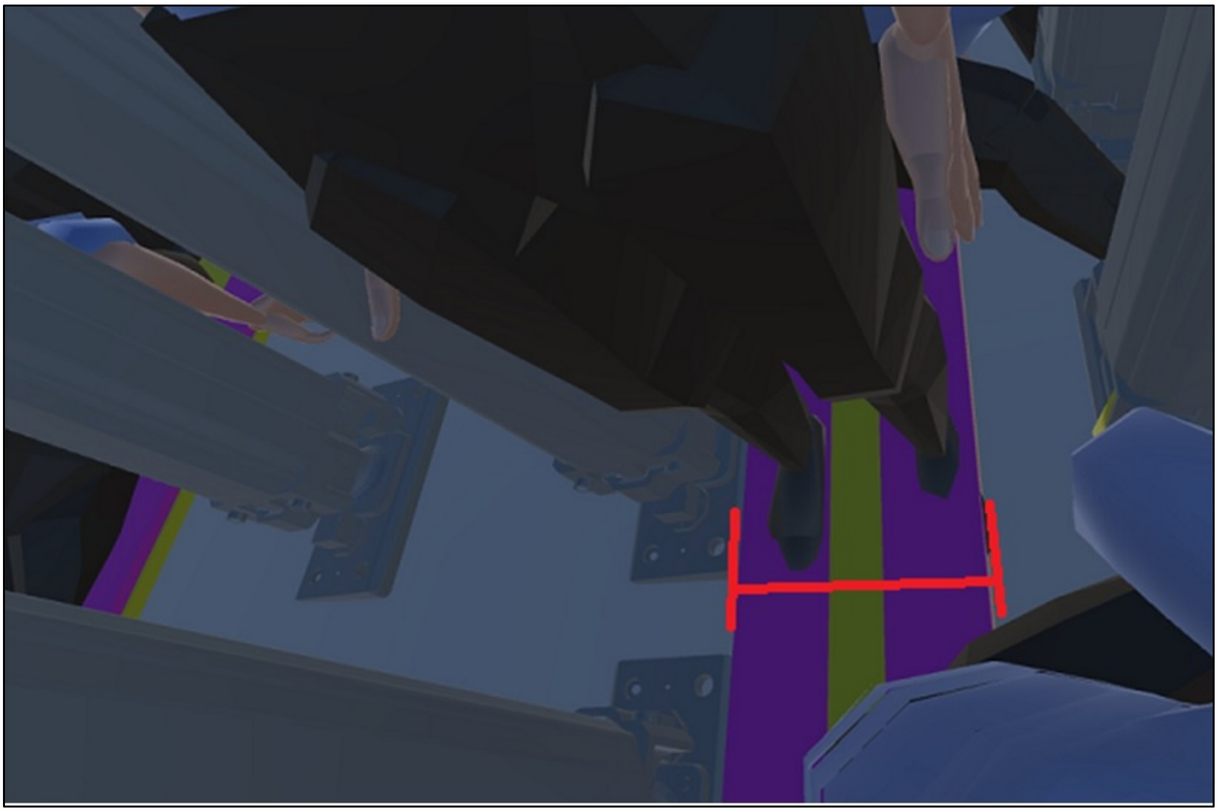

Figure 9 Assessing walkway width from 'Within the missile silo'

7. Assessment

7.1. Assessment

7.1.1. Changing Viewpoints quickly

In a practical exercise a real world CAD Model (of T26 forward silo) was viewed by a design engineer in VR and by immersion within the 'Virtual silo' the design engineer was able immediately to make a design decision regarding the width of a walkway within the Silo.

The chief design advantage of using VR over the more static JACK positioning viewpoints and assessment is speed; the viewer only has to move their head or body or both to visualize a new viewing position whereas within the JACK anthropometric modelling tool the user would laboriously have to move objects then re-select Eye-View cones etc., for each specific viewpoint. In VR the viewer can physically move and move their head viewing angle in real time and make these assessments.

7.1.2. Unique Perspective

Being immersed 'inside' a particular space or piece of equipment, for example a 'silo' – gave the viewer a unique perspective which cannot be gained from looking at a 2D screen of the same environment. This is one of the first aspects of VR that design engineers using the system commented on – especially regarding their immediate 'space' and how close or far objects are from their viewing position. This 'perspective' cannot be appreciated fully by looking at a 2D screen.

7.1.3. Dynamic Aspects of the Task Environment

Within the VR Environment it was possible to simulate a moving platform (e.g. a ship) in various sea states and also simulate the moving viewpoint of a user standing on the ship – with associated (lagged) head movement and its effect on various perceptual tasks e.g. reading a display or HUMMS health status of missiles in silos. In addition it is also possible to simulate various weather effects in the environment and the effect (e.g. perceptually) that this might have on outdoor tasks.
This dynamic alteration of the task environment is not possible to do within JACK on its own.

7.1.1. Facilitate early visualization of the final design solution for the engineers / and customer

Equipment designers often work in isolation and won't necessarily be 'fully aware' of the use and installation context into which the equipment will be installed. Having a 'current state' design in progress model available for all designers (and suppliers/customers) to be able to quickly view and 'jump into' to discuss design constraints / issues / proposals etc. made it a lot more intuitive to look at than the printed page.

7.1.2. Sales and Marketing

Once the engineers are finished with the model (with different sizes of human users performing the tasks), the Model could then be 'cleaned up' / sanitised for use by sales and marketing departments to promote and sell the capability to prospective customers.

7.2. Engineer's Assessment

A Systems Engineer within MBDA was given the opportunity to view an integrated model of a proposed missile silo design and was able to 'step into' the silo using the VR technology as a case study and gave the following feedback:

> *"Thank you for giving my team and me the opportunity to use your Virtual Reality system to review the T26 Sea Ceptor Launcher (MLS) within the Ship silo models. I would like to pass on a few comments for your record:*
>
> *The VR tool has been invaluable is assessing some urgent issues with the Launcher-to-Ship integration. The team has a short amount of time to assess a new silo and walkway design and the impact on the Launcher User operations and was reliant on drawing assessments to find the solution. By modeling the proposal in the VR tool and acting out key activities, we identified an issue and a potential solution.*

Within 24 hours, we had defined and modeled an improved proposal that was shared with the Ship builder, ultimately preventing expensive future changes or sub-optimal end-product.

As an equipment engineer, I can see many benefits in having a tool that allows me to assess the Human-System interfaces and maintenance envelopes within hours of definition. This enables me to iterate and evolve my subsystem design and platform integration in a much shorter timeframe than building prototypes and undergoing physical trials – 6 months of development and trials could be condensed in to a matter of weeks and major risks can be mitigated from the start. This VR capability is a step-change in the company's ability to design for human operators, which is fundamental for our growth from developing missiles to entire weapon systems. In a way, it is the Human-Equipment equivalent to the Simulation and Experimentation capability we utilise for the development of sub-system functional development.

I recommend that a dedicated venue is identified to enable us to use the VR tool outside of the office space and the product is made man-portable (i.e. in a backpack so users are not tied to a workstation) to get the full capability and benefit from this investment and I look forward to making continued use of this tool in the future.
Regards "

Sea Ceptor T26 Launcher Lead

7.3. Downsides

7.3.1. Virtual Nausea

Akin to the real environment, where sea-sickness is always a prevalent issue, VR-Sickness (also called cyber sickness) can also be an issue especially in highly dynamic environments – such as heavy sea states or moving the 'viewer' around the scene. This may limit user's length of time in the VR environment.

8. Future Directions

8.1. Validate Sea States / Movement Models

Currently it's crude guess work, however a more methodical approach would be to try and validate ship movement with sea state according to size/mass and location from ship centre of gravity and then consequential human body movement/head movement resulting directly from the ship movement (which will probably vary according position on the ship) and the human body's natural reaction to 'stabilize' itself to counter the ship movement.

8.2. Simulated Displays

Proposed display Human Computer Interfaces with scripted simulations could be output to Model displays in the appropriate compartment and potential users sat down in front of them (virtually) to evaluate them. This could be subjective evaluation or with a bit more programming objective responses could be recorded and then assessed.

8.3. Workplace Investigations

A Virtual workplace could be set up, including animations of people, simulated immediate audio environment, performing their normal jobs and the 'new design' then assessed within this context, such that dynamic and spatial aspects of the immediate work environment can be taken into account for the design/installation of the new equipment.

8.4. Task Force Simulations

Task force simulations - including communication etc. could be mocked up in a Unity/VR environment and different types of tasks simulated to assess how an individual or 'crew' would interact with other 'simulated' crews in the task force e.g. to look at task force defence (Area Defence). This could be linked up to the output from a Performance Modelling Tool such as the Integrated Performance Modelling Environment (IPME) [4]. Vance, Hughes and Leahy (2017) [5] demonstrated a 2D representation (of an operations room) of resultant workload of crew in response to scenario triggered events. In a UNITY /VR environment an observer could stand in the operations room 'with' the simulated crew and observe both the scenario events and the simulated crew's response to them and resultant workload.

8.5. VR Room

Other systems currently in development which comprise a small laptop computer worn by the viewer in a backpack – connected to a VR headset, which is in effect wireless and enables the user to move freely around – thus facilitating a 'VR Room' into which designers and customers / end users could walk around an evaluate full sized CAD Models from different anthropometric heights. This will probably be possible in the near future and provide a unique way to evaluate and review equipment designs and integration within designated platforms.

8.1. Acoustic Environment

Immediate environment acoustic effects (e.g. engine noise, people talking, orders being called) could also be added for realism and the effect on the task at hand.

8.2. Animate other assets

Animations can be introduced to simulate other ships / aircraft (hostile or friendly) in order to stimulate the user's response to timed events and different types of stimuli - moving towards full scale simulation.

9. Conclusions & Recommendations

The exercise did get positive feedback from the case study regarding a silo walkway (enabling discovery of an issue which otherwise may have been missed). The Unity integrated model and VR viewing thereof did provide a new and unique way of visualizing the current design and potential issues. There may however be feelings of nausea in the subject, if there is a mismatch between the perceptual (moving) scene and stationary (VR viewers' stationary position). Thus parameters controlling the degree and speed of movement should be created to enable fine adjustment. The objective should be to try and simulate the real-world 'moving' environment as close as possible without making them feel nauseas.

Viewing JACK models in Unity & VR will not replace the need for static JACK modelling – but it will give an added perspective. JACK modelling will still be required to conduct precise assessments. VR can be used quickly and effectively to visualise a physical environment and to perform a quick look at ergonomic issues (by a qualified HF person amongst a design team), but it does not replace the need for HF expertise and more detailed modelling. Detailed JACK modelling is still required to do the detailed assessment. It is still the only way that full anthropometric modelling against a requirement can be performed. Recommendations from the assessment can then be visualised in VR to communicate and agree design changes or acceptability of design. The future evaluation / analysis possibilities of using 3D models in a VR observed simulation including animations and scenario driven triggers can produce endless possibilities to aid future design decisions.

Acknowledgements

The views expressed in this paper are that of the authors and do not necessarily represent the views and opinions of MBDA.

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