Optimizing Military Design through Warfighter-Centric Trade-Off Analysis

Executive Summary

Too often, military acquisition responds to preconceived requirements that do not necessarily derive directly from the end user, the Warfighter. To correct this, new modeling and simulation tools are needed to support rapid acquisition that can respond directly to the needs of today's Warfighter. This requires a high level disruptive change to the approach to military design.

We propose a paradigm shift to the current approach to product design as well as a unique, supporting human modeling-and-simulation tool that can evaluate a weapon system's ability to meet Warfighter use requirements through virtual warfighter-in-the-loop trade-off analysis. This approach to warfighter-centric design involves task-based analysis of weapon-systems. This in turn informs and supports engineering design decisions at the earliest stages of product development, thus ensuring warfighter requirements are met while design changes are still affordable and efficient.

Could a fully equipped Warfighter exit this design in an emergency? Don't guess. Let Santos enable your engineers to conduct assessments like this well in advance of prototyping.

The Problem

Currently, design processes front-load traditional engineering efforts with technologies that include Finite Element Analysis (FEA), Computational Fluid Mechanics (CFM), Multi-Body Dynamics (MBD), and others. These technologies are most valuable at the earliest stages of design because they can significantly reduce the need for physical prototypes which would otherwise be needed in trial-and-error approaches to ensuring requirements for structural integrity, aerodynamics, thermodynamics, and the behavior of mechanical systems under the influence of internal and external forces. However, none of these technologies consider a warfighter's use of the design. In addition, current design processes largely developed during WWII are not able to consider the warfighter-in-the-loop until after a design exists. By this time in a weapon system's design cycle, change is not a realistic option.

The discussion above highlights the need for a tool that allows warfighter-in-the-loop requirements to be evaluated at the earliest stages of design. Not only does this tool exist, 60% of the $50M+ invested in its development since 2003 has come from the US Department of Defense. But, before this tool's advantages in increased warfighter effectiveness, reduced time to production and deployment and taxpayer savings can be realized, the design paradigm must change. The following provides some insight into how a truly predictive human model can both provide an addition simulation tool and support the required change in design processes.

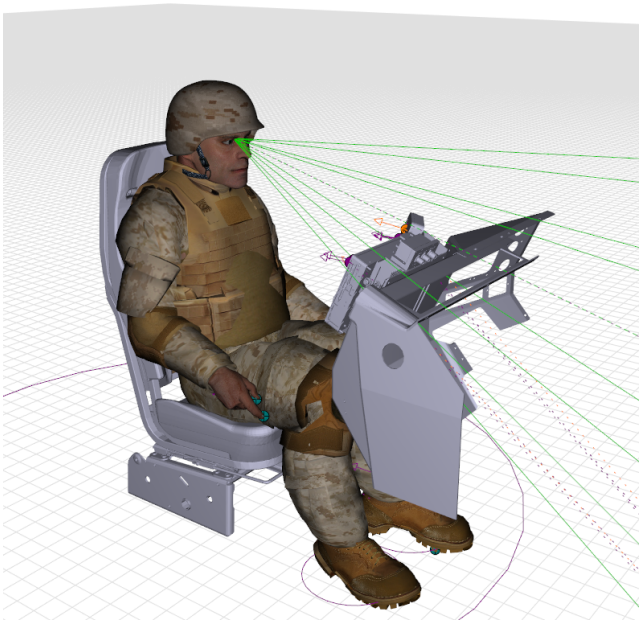
Most digital human models are little more than virtual mannequins with joints that must be manually manipulated before any evaluations can be performed. Accomplishing this is non-intuitive, time-consuming and highly subjective, so virtual mannequins are typically imbued with the ability to use pre-recorded data from motion capture.

Because virtual mannequins must be manually manipulated or driven by pre-recorded data, trade-off analysis is infeasible, so any human-centric analysis must be *reactive* to an existing design. This means that significant resources must first be expended on design and relegates the human-centric component of these types of design processes to trial and error. In the existing design culture this is seen as acceptable as human-in-the-loop evaluations of designs do not typically begin until the end of a rather long list of more traditional engineering efforts. In fact, designers often suggest they do not know how to address human-in-the-loop issues other than by trial and error.

Ironically, those who ultimately use the equipment are effectively treated as the least important design criteria. By the time a virtual mannequin can be deployed, design change is no longer a realistic option, which leads to a "design by committee" approach with an inherent fear to change what has been done in the past. This guarantees that any human-centric issues that exist will be baked into every new design going forward.

The Solution

While Santos® technologies do offer significant advantages for a reactive human-centric analysis (fast, flexible, objective), the differentiating value of this unique human modeling capability is the ability to predict human physical behavior and performance while taking into consideration factors real humans must mitigate when completing tasks in the physical world. These factors include strength, flexibility, fatigue, external forces, balance, avoidance of collisions with objects and self, grasp strategies, and even the need to see the work being done.

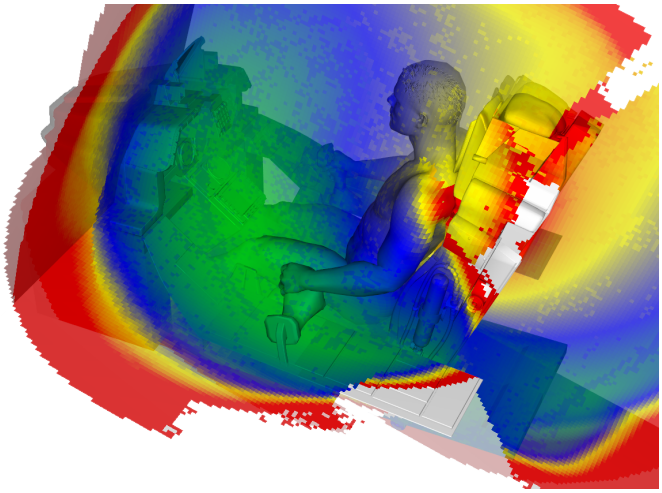


With Santos, it is now easy to thoroughly assess real-world screen placement issues in the conceptual stages of design. Our flexible and realistic virtual Warfighters take the guesswork out of workstation design and human systems integration.

Unlike a traditional virtual mannequin, this predictive approach to modeling the human is ideally suited for trade-off analyses and is therefore proactive. Like FEA, CFM, and MBD, a predictive human model can not

only inform and support product development decisions; it can do so at the earliest stages of design while change is still an option. There is no reason for human-centric design to be conducted by trial and error any longer.

The Santos system is itself novel, but the truly disruptive advantages come from a new approach to design that Santos uniquely supports. Ultimately, having a predictive human model that can automatically react to changes in design allows the human software to be seamlessly integrated with the product analysis software (i.e. stress analysis, structural optimization, etc.). The virtual human can now provide another objective or metric in the automatic system optimization process. This has never been possible before, and we propose exploring and demonstrating this capability with military applications. The foundation for the proposed work has been tested using personal protective equipment[1] [2] [3], but potential application extends to any system that involves human interaction.



Santos virtual human models finally make it possible to analyze highly sophisticated operating environments through task-focused, human performance trade-off analysis. Using Santos at the early stages of design informs and supports design decisions at a time when change is most effective—and is still an option within the design workflow.

[1] Marler, T., Capdevila, N., Kersten, J., Taylor, A., Wanger, S., and MacKiewicz, J. (2016), "Human Simulation for Task-Based Survivability Analysis," *International Journal of Human Factors Modelling and Simulation*, 5(3), 238-262.

[2] Capdevila, N., Marler, T., Mathai, A., Hofer, R. (2013), "Digital Human Modeling for Optimal Body Armor Design," *2nd International Digital Human Modeling Symposium*, July, Ann Arbor, MI.

[3] Mathai, A., Marler, T., Farrell, K., Meusch, J., Taylor, A., Beck, S., Abdel-Malek, K., Corner, B., MacKiewicz, J. (2010), "A New Armor Simulation and Evaluation Toolkit," *Personal Armor Systems Symposium*, September, Quebec City, Canada, The International Personal Armour Committee (IPAC).