Vehicle Simulator Validation – the Power of the System Model

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SUMMARY

To assess the potential usability and crew workload of a future Armoured Fighting Vehicle, a simulator was required to replicate the platform functionality. Specifically, the simulator required validation to ensure that the test data gathered was valid for the system requirement compliance process. With no real vehicle, the validation was based on the platform system model (SysML) that is recognised as the system Single Source of Truth. As the simulator, built using Unreal Engine software, is developed to replicate the SysML, the validation process was to review the simulator functionality against the SysML component parts, and the ability to complete the SysML use cases with the appropriate level of 'flow' where the usability and workload aspects can be assessed. This validation methodology successfully allowed the functional design of the future AFV to be completed early in the design process and reduce future risk to the programme.

KEYWORDS

Simulator, validation, system model

Introduction

Simulators have long been used as part of the vehicle development process. Depending on their use and requirement, these may range from a simple mock-up to a highly detailed, full-motion replica. The digitisation of vehicles, and the proliferating use of software has made vehicles much more capable, with them now often being described as 'software defined'. This digitisation has the potential to overwhelm the user with data/information if it is not presented correctly. The growing use of touchscreens, underpinned by software, has widened the style of human-vehicle interaction, but has also been ridiculed for manufacturers not fully understanding human-machine interaction in a moving vehicle, with its inherent safety issues. These 'software defined' human-machine interaction issues should be addressed early in the vehicle design process, e.g. via the use of human-in-the-loop simulation, prior to real vehicles being produced. Within Systems Engineering, the Verification & Validation (V&V) process provides the opportunity to progressively assure the design, including the use of simulation. An appropriately designed simulator provides the opportunity to assess the human-machine interaction in terms of usability and workload, but the simulation must have the required fidelity and validity. The process of validating a vehicle simulator is common for the replication of an existing vehicle. The process of validating a simulator for a future vehicle is not commonly recognised and understood, therefore a validation methodology for the simulator was developed.

Simulator Functionality – Defined by the System Model

The System Model (SysML) is the vehicle design's Single Source Of Truth (SSOT). It's Use Cases (UC) and sequence diagrams provide the information that defines the vehicle functionality. To

describe how the end-users operate the vehicle systems, UC's and subsequently Operating Procedures (OP) are produced that directly supports the System Task Analysis (STA) [Dobbins, et al. 2022] and the crew instructions. The system model is built in CAMEO (CATIA, Dassault Systemes) by the systems engineers – with the aspects that relate to system User Interfaces (UI) being developed by the HFI team. The validity of the simulator is based on it accurately replicating the SysML / OPs.

Simulator - Design & Build

The HFI SIMulator (HFI-SIM), built on the Unreal Engine (UE) software, provides the synthetic environment and the platform functionality, including the human-machine interaction. The HFI-SIM is assembled from multiple COTS PCs networked together to provide three crew stations (Commander, Gunner and Driver), and two control stations that initiate operational scenario activities and record activity for subsequent analysis. In addition to crew-station specific functionality, the HFI-SIM provides the shared functionality between the Commander and Gunner, e.g. target hand-off, and the ability to initiate system failures and warnings to assess higher workload situations.

HFI-SIM Validation Methodology

The validity of the HFI-SIM is based on it accurately replicating the SysML / OPs. A compliance matrix was developed with each UC feature being an individual compliance item. These are cross-referenced to the appropriate UC/OP, the wireframe illustration for screen description, a control panel/handle illustration, and a video of the function being used and the accompanying control input / display action. The validation process requires that each item is checked by the internal and external validators, and followed by a holistic overview, by experienced AFV end-users, of the simulators ability to run the full UC/OP scenarios with the appropriate user task 'flow'. On successful completion, the simulator was approved for use as a test asset, based on its defined configuration.

Results

The validation exercise demonstrated that the HFI-SIM functionality accurately replicated the SysML as reviewed by a complete examination of each UC feature. The completion of holistic usecases demonstrated that the simulator was capable of effectively running scenarios, that could be assessed with end-users for usability and workload.

Discussion

The HFI-SIM development has to be a joint activity between the Systems Engineering and HFI teams. Simulator (software) developers might, in some circumstances, not be considered to be a part of the HFI Team – this is not the case with the RBSL HFI Team – they are an inherent part, which means they can interact closely and work efficiently with all of the HFI and SysML teams. Similarly, the RBSL trials crew were involved in the iterative simulator development process, this successfully resulted in the simulator being adopted for trials crew platform familiarisation and training, prior to the real vehicles being available.

Summary

The concept of validating a new vehicle simulator, where the vehicle doesn't yet exist, is an uncommon activity. The SysML, being the platform functionality SSOT, was deconstructed and replicated to facilitate the HFI-SIM validation assessment, and support the subsequent V&V progressive assurance process. But as well as having the correct individual UC features, it must also

provide the functionality to assess the effective ‘flow’ of user tasks, for the ultimate assessment of system usability and workload, both for the individual crew members and the team as a whole.

Reference

Dobbins,T., Meeks, R., Hespley, M., Howe, S. & Garland, K. (2022) Task Analysis Within the System Model – The Single Source Of Truth. Conference Proceedings; Ergonomics and Human Factors 2022. Chartered Institute of Ergonomics and Human Factors (CIEHF)