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**REAL-TIME AND HIGH-FIDELITY SIMULATION ENVIRONMENT FOR  
AUTONOMOUS GROUND VEHICLE DYNAMICS**

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**ABSTRACT**

*Integrated simulation capabilities that are high-fidelity, fast, and have scalable architecture are essential to support autonomous vehicle design and performance assessment for the U.S. Army's growing use of unmanned ground vehicles (UGV). The HMMWV simulation described in this paper embodies key features of the real vehicle, including a complex suspension and steering dynamics, wheel-soil models, navigation, and control. This research uses advanced multibody techniques such as minimal coordinate representations with constraint embedding to model complex unmanned ground vehicles for fast mechanical simulations with high fidelity. In this work, we demonstrate high-fidelity dynamics models for autonomous UGV simulations in near real time that can be useful to the U.S. Army for future autonomous ground vehicle dynamics modeling and analysis research.*

**INTRODUCTION**

With increased onboard autonomy, advanced vehicle models are needed to analyze and optimize control design and sensor packages over range of urban and off-road scenarios. Moreover, integrated simulation capabilities that are high-fidelity, fast, and have scalable architecture are essential to support autonomous vehicle design and performance assessment for the U.S. Army's growing use of unmanned ground vehicles.

Recent work at TARDEC has attempted to develop a high-fidelity mobility simulation of an autonomous vehicle in an off-road scenario using integrated sensor, controller, and multi-body dynamics models [1]. The conclusion was that (a) real-time simulation was not feasible due to the complexity of the intervening formulation, (b) models had to be simplified to speed up the simulation, (c) interfacing the sensors was exceedingly difficult due to co-simulation, (d) the controls developed were very basic and could not be optimized, and (e) a rigid terrain model was used.

The JPL ROAMS ground vehicle simulation framework is based on the JPL Darts/Dshell simulation architecture [2], [3], [4], [5]. ROAMS and the underlying architecture have been successfully demonstrated at JPL in several space mission-critical scenarios where a high degree of mission

complexity, real-time performance, and extensive sensor/actuator/control integration were necessary. The underlying framework has been applied to a variety of mission-critical simulation needs for NASA missions across multiple domains (cruise/orbiter, landers, and rovers) over the years. The architecture has supported real-time embedded hardware-in-the-loop use to large-scale Monte Carlo based parametric studies. For further information about the ROAMS, please visit the JPL DARTS Lab website: <http://dartslab.jpl.nasa.gov>.

ROAMS is unique in its integrated approach to straddling the multi-function high-fidelity dynamics, sensors, environment, control, and autonomy models that are key attributes of future Army unmanned ground vehicles (UGVs). This project will facilitate the transfer of this technology to TARDEC so that customers such as RS JPO and DARPA can be supported.

This project is a pilot effort to demonstrate the application of the ROAMS modeling approach for addressing the fidelity and speed bottlenecks for TARDEC and the Army's needs for the evaluation and testing of autonomous ground vehicles. The simulation architecture represents a shift in paradigm in empowering analysts with full visibility and control in tailoring key elements of the simulator. This

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