USER STORY

Rod Millen Special Vehicles Develops Suspension System for Military Vehicle Using MathWorks Tools

To prevent casualties on the battlefield during high-risk reconnaissance and targeting missions, the military is exploring the use of unmanned ground vehicles (UGVs). These vehicles must be designed to navigate over rough terrain, climb large obstacles, and continue operating after accidental rollovers.

Using MathWorks tools, Rod Millen Special Vehicles (RMSV) designed and optimized the suspension components and active control systems of a technology demonstrator UGV called the Unmanned Ground Combat Vehicle (UGCV) for the Defense Advanced Research Projects Agency (DARPA).

"The UGCV must be capable of climbing over obstacles taller than itself. In case of a rollover, the suspension assembly rotates back to the ground and the vehicle continues to move while inverted," explains Dr. Eric Anderfaas, senior scientist, RMSV. "MathWorks tools helped us ensure that the suspension could meet these requirements on time and within budget."

THE CHALLENGE

RMSV had to design the UGCV to survive an airdrop landing by parachute impacting the ground at 8 m/s, traverse a .25 meter step at 20 km/hr, and climb a one-meter step. All these tasks had to be accomplished without human intervention.

Past experience and early simulation results led the team to design a vehicle with six wheels driven by in-hub motors. Each hub was mounted at the end of a suspension arm to enable independent, continuous rotary articulation about the lateral vehicle axis. These articulated joints used active dampers to ensure real-time movement control of each suspension arm. A primary objective in the simulations was to develop and test the control laws for the active damper and positioning systems before building hardware.

RMSV-designed Unmanned Ground Combat Vehicle.

RMSV needed to perform dynamic analysis of key operational states of the vehicle, taking into account parameters such as mass properties of the vehicle and suspension components.

Engineers were expected to deliver a fully functional suspension system capable of supporting extensive vehicle testing in the field. Due to the aggressive timeline for the delivery of the vehicle, the suspension design and control system had to be developed in parallel with the design and manufacturing of the UGCV's chassis and hybrid-electric power system. To meet the delivery deadline, RMSV had to identify any problems in the suspension during design.

THE SOLUTION

Using MathWorks tools, RMSV developed, simulated, and tested the control algorithms for the active suspension and vehicle model, then generated code from the control law models for real-time testing—without building multiple hardware prototypes. By transition-

THE CHALLENGE

To design an innovative active suspension system for an unmanned ground vehicle (UGV)

THE SOLUTION

Use MathWorks tools to design and optimize the suspension components and active control systems of the UGV

THE RESULTS

- Defect detected before production
- Full-vehicle hardware prototypes eliminated
- Development time reduced

> *MATLAB, Simulink, and SimMechanics enable us to quickly perform modeling, simulations, and dynamic analysis of next-generation, off-road vehicle suspensions. I consider these tools to be essential for efficient design of advanced control systems.*
>
> Dr. Eric Anderfaas, Rod Millen Special Vehicles

ing from the computer into high-functionality hardware, they completed this portion of the project in weeks instead of months.

"The extensive dynamic analysis conducted with MathWorks tools provided a solid foundation for determining feasible design approaches," explains Anderfaas. "Vehicle testing has validated our analysis and the vehicle's performance has met our high expectations."

They first used MATLAB® to recreate the basic control laws, which consisted of standard passive and "Skyhook" damping terms.

After evaluating suspension concepts, they used MATLAB and Simulink® to model and simulate their vehicle concept and to optimize the vehicle's handling at speeds of up to 40 km/hr. They developed a complete mechanical model of the vehicle's spring and damper components in Simulink using body, joint, sensor, and actuator blocks from SimMechanics.

Using Real-Time Workshop®, engineers ported the control laws developed during simulation from Simulink to the onboard control system and generated code automatically from the optimized Simulink model. RMSV used xPC Target to realize high-bandwidth, real-time control of vehicle suspension components by running the C code on a high-performance embedded PC-104 form factor computer located within the vehicle.

RMSV, in partnership with Lockheed Martin Missiles and Fire Control, has conducted basic mobility and reliability testing of the UGCV at Sandia National Laboratories and the Army's Yuma Proving Ground. The U.S. military plans to use UGVs for tasks including scouting, relaying intelligence, breaching obstacles, firing remote weapons, and reducing soldier payload burden.

THE RESULTS

- **Defect detected before production.** A discrepancy between a SimMechanics simulation and observations from their in-house shock dynamometer revealed a minor manufacturing defect in the prototype suspension module. "SimMechanics helped us to identify a performance problem and find a solution during the design stage, which saved us several days of testing time," says Anderfaas.
- **Full vehicle hardware prototypes eliminated.** Because they were able to develop a complete model of the UGCV and run simulations, RMSV did not need to create costly hardware prototypes of the vehicle or multiple subassemblies to estimate the vehicle's mobility capabilities.
- **Development time reduced.** MathWorks tools enabled high-confidence parallel path design and functionality verification of the complex suspension. Anderfaas adds, "If we had to wait until the rest of the vehicle was complete before testing our suspension design, it would not have been possible to meet our aggressive delivery date."

To learn more about Rod Millen Special Vehicles, visit **www.rodmillen.com**

APPLICATION AREAS

- Aerospace and defense
- Automotive
- Control design
- Mechanical modeling
- Production code generation
- Hardware-in-the-loop simulation

PRODUCTS USED

- MATLAB
- Simulink
- SimMechanics
- Real-Time Workshop
- xPC Target

www.mathworks.com

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