A summary of U.S. armored combat vehicle modelling and simulation activities

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ABSTRACT

This paper provides an overview of the modelling and simulation work jointly performed by the Government and Industry in characterizing US Armored Vehicle Technology. The genesis of these simulations is the HITPRO Armored Model developed by the General Electric Company in consort with the Government. Subsequently, with the incorporation of gun dynamics and interior ballistics in the model by the Government these models have become known as the Integrated Weapon Armored Vehicle Model (IWAVM). This paper begins with an introductory discussion of the various subsystems and components included in the model and identifies the US Armored Vehicles that have been modelled to date. Next the paper focuses on one particular family of armored vehicle models which the authors feel possess enormous computer aided design potential. The paper concludes with a discussion of several current applications of the IWAVM methodology.

INTRODUCTION

Since 1972 the General Electric Co. and the Government have jointly developed engineering simulations for the following US armored vehicles:

- o M60A2 Combat Tank
- o M60A1/Add-On-Stabilization (AOS) Combat Tank
- o M60A3 Combat Tank
- o High Mobility Agility Vehicle (HIMAG) Test Bed
- o High Survivability Test Vehicle-Light (HSTV-L) Testbed
- o M1/M1A1 Combat Tank
- o Mobile Protected Gun Systems (MPGS) Conceptual Family of Armored Vehicles

These simulations contain detailed descriptions of the following components, subsystems, scenario conditions and human performance characteristics:

- o Weapon/Turret Servo Drives
  - oo Control Compensation
  - oo Hydraulics
  - oo Load Dynamics
  - oo Disturbance Torques
- o Chassis/Suspension
  - oo Tracked Vehicle
  - oo Wheeled Vehicle
- o Exterior/Interior Ballistics
- o Gun Tube Dynamics
- o Fire Control
- o Sighting System
- o Tracking System
  - oo Gunner(Man-in-the-Loop)
  - oo IR & Milli-Meter Wave Radar
- o Weapon System Recoil
  - oo 75 mm
  - oo 90 mm
  - oo M68 105 mm (Standard)
  - oo Super Long 105mm Recoil
- o Scenario Conditions
  - oo Terrain Micro Profile
  - oo Firer's Path Motion
  - oo Target Path Motion

IWAVM SUBMODELS DISCUSSION

Figure 1 depicts a simplified block diagram typical of one of the weapon systems modelled above. Included are the fire control, the weapon/turret servo drive, and the sight driven reticle servo system, and tracking system in this case is a human. The following data are provided in order to provide qualitative examples of the output from this and the other simulations.

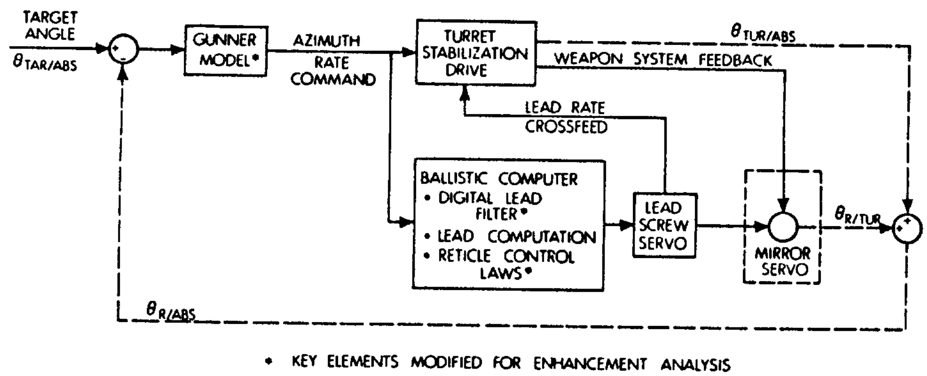

Figure 1. Closed Loop Block Diagram of Generic Driven Reticle Fire Control.

Figure 2 depicts a comparison of this simulated weapon system with test data obtained from laboratory tests of the actual weapon system. Specifically, the Combat Test Agency's (CSTA) Moving Target Simulator (MTS) which is a dome test structure located at Aberdeen Proving Ground, MD was used. A servo driven laser beam was projected against the inner walls of the MTS dome and the gunner tracked the spot. Various IR, camera and other instrumentation are used to monitor weapon and reticle to target spot location and the gunner's handle bar responses. For the hardware validation work the actual gunner's handle bar responses were used as input to the simulation. The comparison between the actual and simulated weapon to target spot offset were deemed remarkable in that they involve three major subsystems; the weapon/turret servo drive, the fire control, and the sight driven reticle servo drive, as well as the cross-feed compensation networks.

Figure 3 depicts a comparison of the IWAVM simulated and actual vehicle pitch motion for this same system. the test data were obtained from the CSTA Aberdeen Proving Ground Stabilization Course. Excellent agreement exists between the two sets of data in terms of amplitude, frequency content, and signal phasing. The chassis/suspension model used in IWAVM may be described as:

oo Generic - The model requires only vehicle physical data such as weights, inertias, dimensions, locations of vehicle and turret center-of-gravities, location of roadwheels, suspension torsion bar/hydroneumatic characteristics, etc.

oo Six Degrees of Freedom - The basic model used for simulating hull dynamics is a six degree of freedom model in which the linear (forward,lateral, & vertical) and attitude (roll, pitch, and yaw) motions of the hull are calculated. In addition

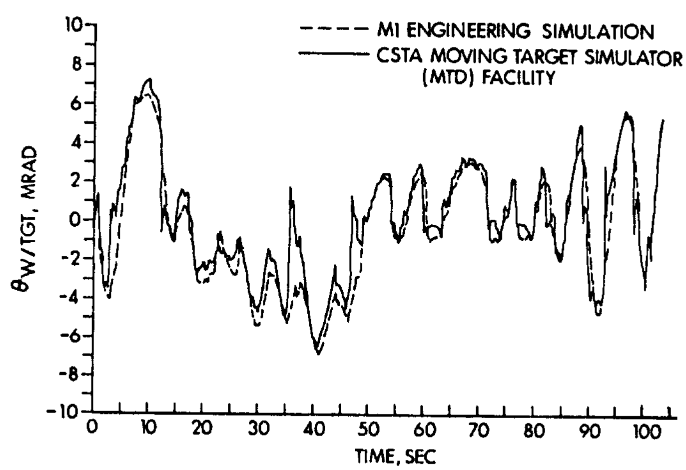

Figure 2. Actual and Simulated Weapon to Target Offset/Aberdeen Proving Ground Moving Target Simulator (MTS) Facility.

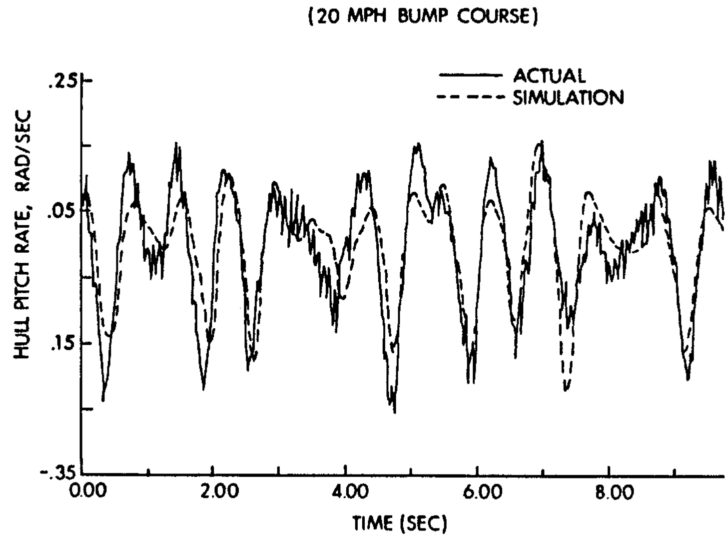

Figure 3. Actual and Simulated Vehicle Pitch Motion/Aberdeen Proving Ground Stabilization Course/

to hull dynamics the suspension model permits vertical motion of the wheels relative to the hull but no lateral or forward relative wheel motion. Lateral and vertical tire compliance relative to the tracks are also computed.

oo Cost Efficient - The chassis/suspension model requires a 1 milli-second (ms) integration step and will run in real time on a CDC CYBER 7600 Digital Computer.

Figures 4 and 5 depict a comparison of actual and simulated human responses. The actual human responses where obtained from CSTA's MTS Facility using maneuvering target path motion to drive the laser servo. This same path motion was used as input to the simulation. Shown in the figures are tracking errors (offset between the reticle and the target) and the gunner's handle bar responses (commanded rate into the systems fire control and turret servo drive - See Figure 1). The gunner model used in this analysis is based on the optimal control gunner model developed by Dr. David Kleinman of the University Connecticut. The overall agreement between the simulated gunner and the actual gunner is of good quality.

Finally, figure 6 depicts power spectral density comparison of simulated and actual weapon tube dynamics. Strain gauge data proportional to the independent flexing of the muzzle obtained from field tests conducted by the Ballistic Research Laboratory was used in comparisons. The gun dynamics model used in the IWAVM Simulation was jointly developed by Dr. A. P. Boresi and Professor R. E. Miller of the University of Illinois. A comparison of the spectras indicate nominally the same resonance and amplitudes.

In addition to the characteristics described earlier, these simulations:

oo compute required offset necessary to hit the target as well as actual weapon to target offsets. These data are used to estimate delivery accuracy capabilities of the system. In reality the armored vehicle simulations are used in conjunction with interactive delivery accuracy programs known as DELACC. These interactive programs are structured in two parts.

- DELACC PART 1 which analyzes the simulated gunner's tracking error and tracking error rates by comparing error magnitudes against established criterion based on when actual gunners executed ranging, lead insertion and firing events. The times for these events to occur are based on time distributions developed by Army Material Systems Analysis Activity (AMSAA)

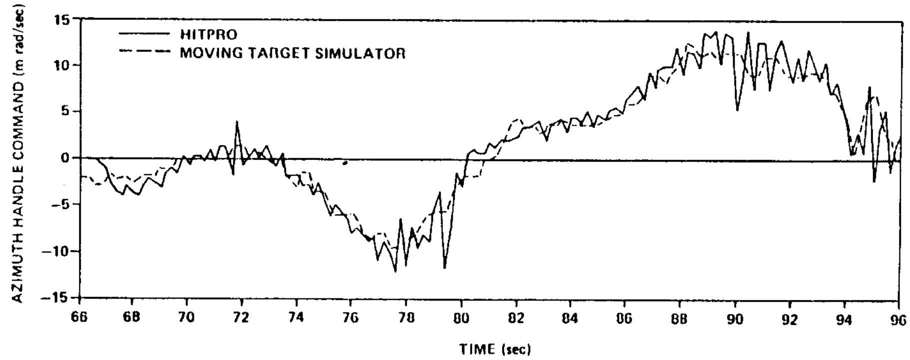

Figure 4. Actual and Simulated Gunner Handle Bar Response/Aberdeen Proving Ground Moving Target Simulator (MTS) Facility.

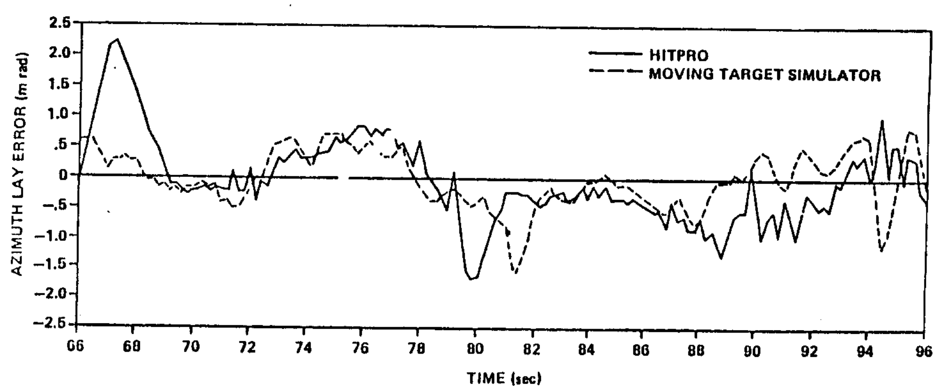

Figure 5. Actual and Simulated Gunner Tracking Error/Aberdeen Proving Ground Moving Target Simulator (MTS(Facility.

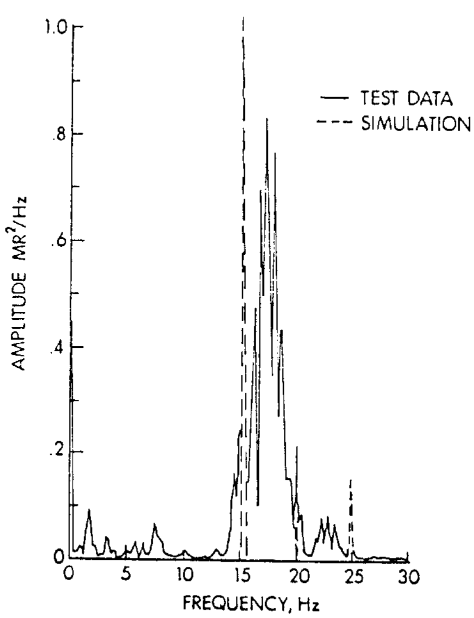

Figure 6. Power Spectral Densities of Actual and Simulated Weapon Tube Muzzle Flexure/Aberdeen Proving Ground Stabilization Course.

- DELACC PART 2 which combines the difference between required and actual weapon to target offset error with stochastic errors such as random errors, fixed biases, and variable biases not modelled in the armored vehicle engineering simulations to calculate system hit probability as a function of scenario conditions.

oo while programmed in Fortran 4 and Fortran 77 maybe converted to higher level simulation languages such as the Advanced Continuous Simulation Language (ACSL) or MIMIC Language since all of model and simulations documentation includes analog representation of all of the major subsystems including the gunner model.

(MPGS) CONCEPTUAL FAMILY OF ARMORED VEHICLES

In 1982 the Government in consort with the General Electric Company and the Business and Technological Systems (BTS), Inc. began modifying the High Mobility and Agility (HIMAG), High Survivability and Test Vehicle-Light and M1 engineering simulations to emulate the following MPGS concept vehicles identified in Table 1. In all, there are 168 possible concept combinations of fire control, chassis/suspension, and weapon types. The emphasis during the MPGS evaluation focused on quantifying delivery accuracy differences as a function of different combinations of fire control, chassis/ suspension configurations and weapon types. The simulation development phase of the MPGS evaluation consisted of the following broad tasks:

oo Implementation of a methodology which would permit easy and rapid rescaling of the HIMAG chassis/suspension model in order to accommodate vehicles of different sizes and weights.

oo Extending the chassis/suspension model in order to simulate wheeled vehicle as well as tracked vehicle concepts.

oo Modularizing suspension data inputs so as to characterize different suspensions, e.g., hydropneumatic, high strength torsion bar and hybrid of the two.

oo Embedding different fire control systems such as the M1 driven reticle and HSTV-L Auto Track/ Rate Aided systems into the HIMAG Simulation. This task required insuring compatibility between the embedded fire control and the HIMAG gun/turret stabilization drives.

oo Incorporating the ballistics and recoil forces and displacement data into the MPGS Simulations for the different weapon systems.

oo Interfacing the MPGS Simulations with the DELACC performance models.

One of the most significant tasks associated with the MPGS which stands alone in it's importance was the development of interactive software procedures which queried the user and allowed the user to:

oo build the concept vehicle of interest by selecting and integrating any combination of fire control, chassis/ suspension, and weapon type from Table 1

oo select from a multitude of scenario conditions different terrain types path motions, vehicle speeds, and target location, and

oo evaluate different engagement situations such as single shot versus rapid or burst fire.

Some of the MPGS application work will be discussed in the next section. Before leaving this section however it is worth noting that the modular methodology that was developed along with the interactive software makes the MPGS modelling/simulation work a valuable tool for computer aided armored vehicle design. Furthermore the list of Table 1 of chassis/suspension configurations, fire control systems, and weapon types may be easily extented to included other conceptual systems.

IWAVM APPLICATIONS

Historically the IWAVM simulations have used in support of various armored vehicle studies such as:

- o Conceptual Design
- o Design Trade-Offs
- o Effectiveness
- o Predictive Performance
- o Diagnostic
- o Research

TABLE 1. SIMULATED MPGS ARMORED VEHICLE CONCEPTS

1. FIRE CONTROL SYSTEMS:

- o Continuous Driven Reticle (Both Azimuth and Elevation Axes)/Manual Tracking.
- o Continuous Driven Reticle (Azimuth Axis Only)/Gun Director (Elevation Axis Only)/ Manual Tracking.
- o Gun Director (Both Azimuth and Elevation Axis)/Manual Tracking.
- o Gun Director (Both Azimuth and Elevation Axis)/IR Auto Tracking.
- o Gun Director (Both Azimuth and Elevation Axis)/IR Auto Tracking/Rate Aided.
- o Gun Director (Both Azimuth and Elevation Axis)/Manual Tracking/Rate Aided.

2. CHASSIS/SUSPENSION CONFIGURATIONS:

- o 15-Ton Tracked Vehicle/High Strength Torsion Bar.
- o 17-Ton Tracked Vehicle/High Strength Torsion Bar.
- o 21-Ton Tracked Vehicle/Hydropneumatic Suspension.
- o 21-Ton Tracked Vehicle/High Strength Torsion Bar.
- o 21-Ton Tracked Vehicle/Hybrid Suspension - (Hydropneumatic/High Strength Torsion Bar) Suspension.
- o 16-Ton Wheeled Vehicle (6 Wheels x 6 Independent Suspension Points).
- o 19-Ton Wheeled Vehicle (8 Wheels x 8 Independent Suspension Points).

3. WEAPON SYSTEMS.

- o 75 mm.
- o 90 mm.
- o Standard M68 105 mm.
- o Low Recoil 105 mm.

Presently the MPGS and M1/M1A1 simulations are being used in the following fire control related studies:

o Multi-Sensor Target Acquisition (MTAS) System - This study focuses on the use of parallel independent tracking systems using a combination of man-in-the-loop, and IR and milli-meter wave radar trackers. The objective is to develop a multiple target engagement acquisition and tracking fire control.

o Digital/Optimal Versus Analog/Classical Control - This study deals with the design and evaluation of a digital/optimal controller as a replacement to the conventional analog control compensation presently used in weapon/turret servo drive systems. The study focuses on the impact of such controller on fire-on-the-move inertial stabilization performance and takes into account differences in chassis/suspension ride quality.

o Emulation of Gun Director Fire Control by a Driven Reticle System - This study deals with a design modification to a classical driven reticle system in order to attain gun director performance. The hardware modifications involve relatively simple analog signal flow changes in conjunction with fire control digital filtering changes. The study also addresses how the man-in-the-loop must modify his performance in order to take advantage of the increased weapon system capabilities.

SUMMARY

This paper highlighted some of the aspects and armored vehicle modelling and simulation activities ongoing at Aberdeen Proving Ground, MD by the Government. It was intended to be an introductory overview on this subject and not a complete compilation of the work. Further information on the work should be directed to the authors.