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This project was originally titled the Hybrid Electric Combat Vehicle (HECV); hence the title on the cover. It was subsequently named the Combat Hybrid Power System (CHPS) project and is so-called hereafter. This paper presents two different analyses of the vehicle performance characteristics of the CHPS. The first used a panel of military subject matter experts to examine the validity of CHPS performance requirements. The second ran virtual exercises using the Modular Semi-Automated Forces (ModSAF) model to gain insight into the relative effectiveness of a CHPS system in conducting Army After Next (AAN) combat missions. Results from the SME Requirements Analysis survey indicate that currently CHPS cross country speeds may be too high for crew safety and command and control reasons. Results of the ModSAF study suggest that the CHPS may prove to be more mobile, survivable, and lethal in an Army After Next battlefield than other candidate systems.

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1. INTRODUCTION

1.1 Purpose

This project was originally titled the Hybrid Electric Combat Vehicle (HECV); hence the title on the cover. It was subsequently named the Combat Hybrid Power System (CHPS) project and is so-called hereafter. This paper presents two different analyses of the vehicle performance characteristics of the CHPS. The first used a panel of military subject matter experts to examine the validity of CHPS performance requirements. The second ran virtual exercises using the Modular Semi-Automated Forces (ModSAF) model to gain insight into the relative effectiveness of a CHPS system in conducting Army After Next (AAN) combat missions. Results from the SME Requirements Analysis survey indicate that currently CHPS cross country speeds may be too high for crew safety and command and control reasons. Results of the ModSAF study suggest that the CHPS may prove to be more mobile, survivable, and lethal in an Army After Next battlefield than other candidate systems.

1.2 Contract Overview

The Defense Advanced Research Projects Agency's (DARPA's) CHPS contract included requirements to:1) conduct an assessment of the notional vehicle performance characteristics/requirements, and 2) demonstrate the proposed notional vehicle concepts in a virtual environment. Included in these efforts was the need to perform the following subtasks:

- Validate CHPS requirements
- Certify the Mission Profile and identify high payoff vignettes for examination later in the System Integration Laboratory (SIL)
- Gain insight into how the CHPS vehicle interoperates with other battlefield systems, on a unit mission, in a force-on-force combat environment
- Assess the warfighting/battlefield potential of the CHPS notional vehicle
- Perform trade studies of performance characteristics and the power needed to meet them.

The ADST II team has proposed and conducted a series of efforts, using a variety of methods, designed to address these requirements. This paper describes a series of battlefield effectiveness efforts, using both subjective and objective methods, that ADST II conducted to examine the issues listed above

1.3 Experiment Overview.

There is no single best way to address issues regarding the potential battlefield effectiveness of a system that is still in a concept development phase. We chose a combination of subjective and objective methods to gain insight into CHPS issues.

2 Applicable Documents

2.1 Government

- ADST II Work Statement for Hybrid Electric Combat Vehicle Quick Look Study, Oct 6,1997, AMSTI-97-WO74, Rev 3.0

2.2 Non-Government

N/A

3 Conduct of The Experiment

3.1 CHPS Requirements Analysis

The subjective CHPS Requirements Analysis consisted of canvassing several noted experts in the field of tactical vehicle operations to get their assessment of several of the CHPS performance characteristics which have been identified as design drivers (including mobility and silent operations). We used the collective professional opinions of six experts in the field of tactical vehicle performance characteristics. Those surveyed were:

- GEN (Army, ret) Paul Gorman (renowned training and technology visionary, veteran of several Defense Science Board studies, and head of John Gully's DARPA TTO Senior Advisory Group)
- MG (Army, ret) Bob Sunell (armored cavalryman, veteran of several Army vehicle programs including the M1 tank and the Family of Armor Vehicles, and a member of John Gully's Senior Advisory Group)
- COL (Army, ret) Ed Bryla (former director of the Force Development Directorate, the requirements office of the U.S. Army Armor School at Fort Knox, for seven years)
- COL (Army, ret) Jack Klevecz (former head of TRADOC's Integrated Battle Lab and an advisor to TRADOC's Army After Next project for the last year);
- Mr. Gene Baker (of TARDEC, a former combat arms officer, now heavily involved in armored combat vehicle development, closely aligned with the Army After Next project, and an advisor to John Gully)

- COL (Army, ret) Glenn Snodgrass (one of the authors of this report, a 28-year veteran who commanded Army units with several kinds of armored vehicles through Brigade level).

In addition to those expert assessments, we also reviewed the papers from the September , 1997 meeting of the AAN Mobility Integrated Idea Team, and the requirements associated with the Future Scout/Cavalry System vehicle as determined by the Force Development Directorate at Ft. Knox. Each of the experts was shown several of the initial design characteristics of the CHPS notional vehicle and asked for their opinion. Results reflect comments made during telephone interviews that took place from 1 - 15 September 1997.

3.2 ModSAF Quick Look Study

We augmented these subjective observations with a pilot simulation study of the potential combat effectiveness of proposed CHPS capabilities. This study used the Modular Semi-Automated Forces (ModSAF) model in a series of virtual force-on-force engagements. This section describes the model, and how we modified and used it during a Quick Look study at the U. S. Army Simulation Training and Instrumentation Command's (STRICOM's) Operational Support Facility in Orlando from 12-16 October 1997.

3.2.1 ModSAF Model Description

An outgrowth of DARPA research into Computer Generated Forces, ModSAF is a physics-based, entity-level simulation that replicates the performance characteristics (such as lethality, vulnerability, and maneuverability), subsystems (such as weapons, sensors, communications devices, drive trains), and battlefield behavior of actual or postulated combat vehicles. ModSAF currently provides a warfighter with tactical control over combat entities and units engaged in a real time simulation of a large scale, complex, virtual battlefield. Fully compliant with the Distributed Interactive Simulation (DIS) standard, ModSAF can interface with other simulations to support the execution of the missions with a synthetic battlefield. ModSAF modeling permits the interoperation of the CHPS simulation with a wide variety of simulations as ModSAF migrates to the DARPA High Level Architecture (HLA) environment. ModSAF warfighting assessments can be conducted in an iterative fashion with the performance simulations, allowing insights to be shared between them.

3.2.2 Test Objectives

Specific objectives of the Quick Look Study were to:

- Examine the sensitivity of ModSAF model behavior to differences in vehicle performance characteristics
- Examine the sensitivity of selected mission and vehicle performance measures to differences in vehicle performance characteristics
- Examine the adequacy of selected virtual combat scenarios for possible future studies

- Examine the value of the currently proposed CHPS mission profile and ModSAF's capability to execute it
- Gain insight regarding capabilities of a CHPS-powered vehicle relative to incumbent systems (specifically the M3A3 Bradley Scout vehicle) in executing selected missions.

3.2.3 Simulation Testbed Configuration

The network configuration used to support the Quick Look Study is shown in Figure 3-1. A list of the simulation controllers is at Appendix A. The operators and ModSAF engineer were contracted employees provided by the Advanced Distributed Simulation Technology II contract. The ModSAF workstations supplied OPFOR and BLUFOR for the exercise. The DIS Test Suite provided a data logging capability, while the Meta VR stealth provided a three dimensional view of the battlefield.

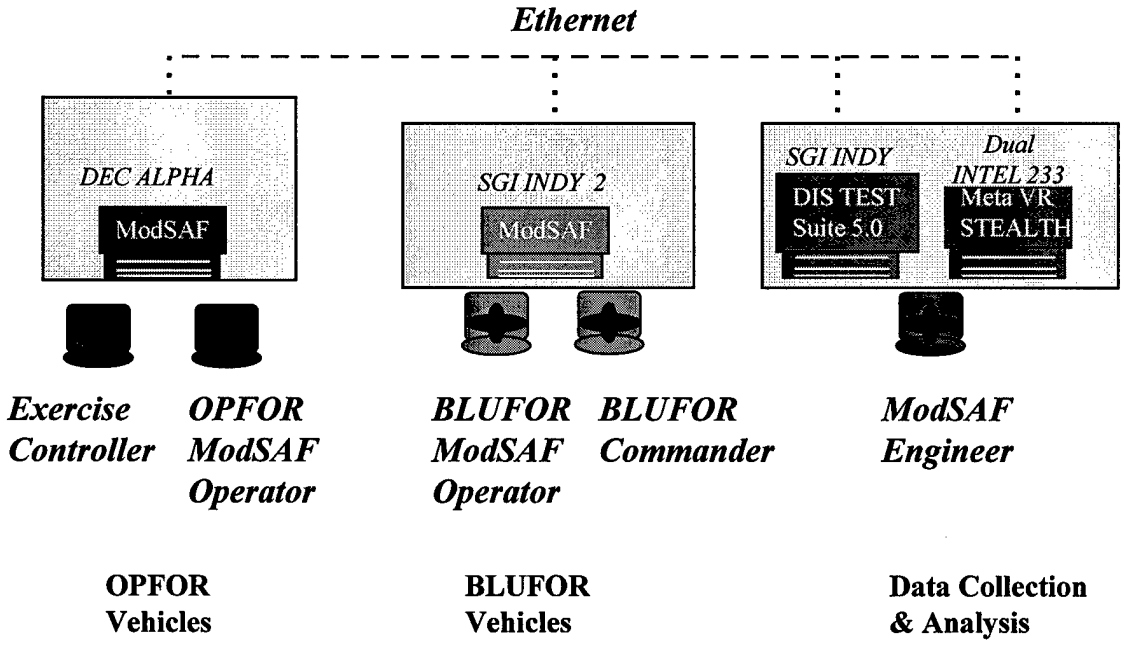

Figure 3-1 Study Network Configuration

3.2.4 Forces Simulated

BLUFOR consisted of one six-vehicle platoon of CHPS notional vehicles or one six- vehicle platoon of Bradley M3A3s. The OPFOR consisted of two Motorized Rifle Companies, each with two platoons (three vehicles each) of BMP2s and one platoon (three vehicles) of T72 tanks. The two companies were never employed simultaneously against the BLUFOR, but in

one of two sequences: (lead-trail down the same avenue of approach, or from a left and a right avenue of approach). Each force was given a battery of artillery in immediate, direct support. BLUFOR used a battery of ModSAF 155mm artillery to emulate the function of the Advanced Fire Support System (AFSS), an unmanned system of 155mm artillery that can be dropped onto the battlefield within range by parafoil. OPFOR used a battery of standard 122mm artillery.

3.2.5

Terrain Database

Due to time constraints, we were only able to work with a single terrain database. We selected the Fort Knox, Kentucky terrain database over the other available database (National Training Center at Fort Irwin, California), because it provided more variety of terrain (rolling hills, streams and ford sites, and forests and vegetation).

3.2.6 Vehicle Performance Characteristics

The CHPS vehicle was implemented in ModSAF by modifying the existing model for the M3A3 Bradley. The ModSAF Engineer made the following changes to the baseline M3A3:

- Vulnerability - The front half of the vehicle hull was given armor protection equivalent to that of an M1 tank
- Vehicle Dimensions - 14 feet x 8 feet x 5 feet (LxWxH).
- Electro Thermal Chemical (ETC) Gun - Equivalent to 105mm SABOT (Kinetic Energy round
- Speed - Increased for both Road and Cross Country movement
- Signature - Reduced to be about 40% of that of the Bradley

Appendix B contains a more detailed list of the characteristics of vehicles modeled in this exercise. Appendix C presents a probability of detection by range of the CHPS vehicle.

3.2.7 Scenario

The military scenario was placed in a simplistic political situation, not unlike the Iraqi threat along the Kuwait border. The timeframe (2015-2020) and certain futuristic assumptions were similar to those of the Army's Army After Next (AAN) Project. A belligerent neighbor has threatened a nation friendly to the United States. The U.S. leadership hoped, by quick, early and decisive intervention, to prevent invasion and bloodshed, and to provide some time so that negotiations and diplomacy could end the crisis peacefully. The mission of the first-arriving forces was to quickly establish a strong military presence in the friendly country; advance quickly to positions along the threatened border; gain and maintain contact with the belligerent force; delay any enemy advance long enough to allow the remainder of the early forces to get into strong defensive positions; use indirect fires, rather than direct fires, whenever possible; and avoid decisive combat if possible, but attrit the enemy force if unable to avoid combat.

The vehicles initially conducted a 5-mile high speed road march from Point A to Point B (See Figure 3-2). Next they conducted a 10-mile cross-country move (at maximum cross country speed) from Point B to Defensive Battle Position 2 (BP-2) indicated on the map as Position C. They then moved approximately 2 miles to Defensive Battle Position 1 (BP-1) indicated in the figure as Position D. Here they prepared to defend against the OPFOR attack from across the border. Their mission was to defend and attrit the enemy as much as possible (using direct and indirect fires as needed) without becoming decisively engaged. If seriously

threatened, they were instructed to delay back to BP-2 as quickly as possible to defend against the enemy once again. Note that BP-1 offered better cover and a better line of sight to enemy approach routes and was, therefore, considered a superior defensive position.

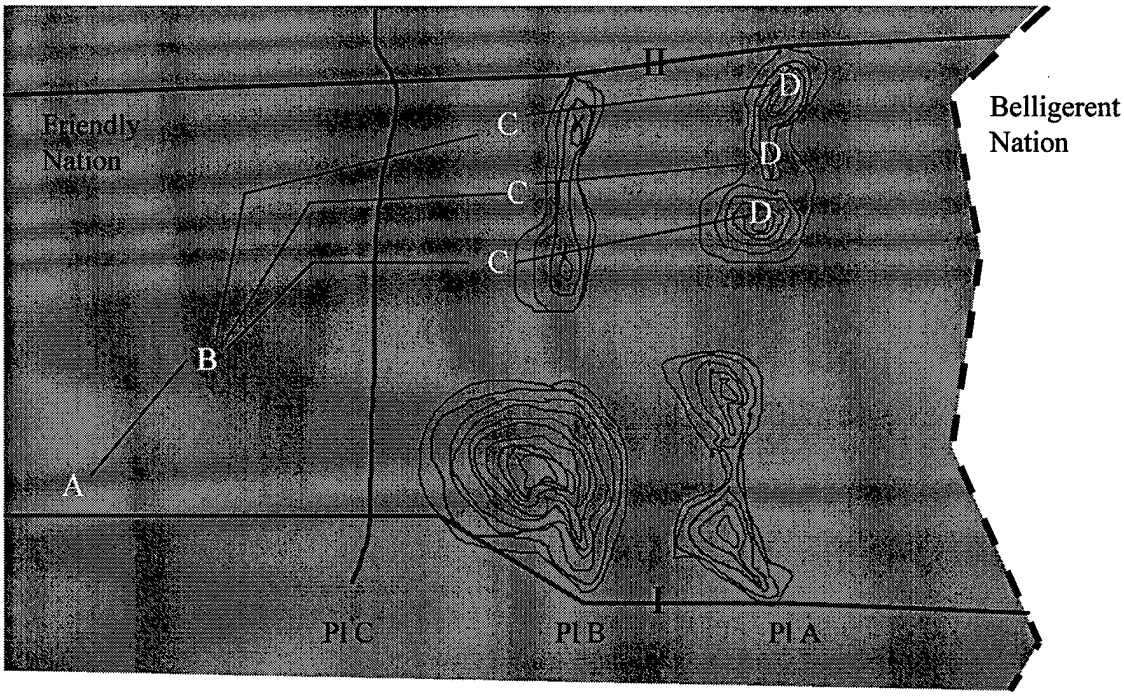

Figure 3-2 BLUFOR Overlay

3.2.8

Test Run Matrix

Table 3-1 presents the test run matrix for this exercise:

Phase	CHPS Runs	Bradley Runs
High Speed Route March	CHPSRM 1-5	BRADEF 1-2 BRADRM 3-5
Cross Country	CHPSRM 1-5	BRADEF 1-2 BRADRM 3-5
Defensive Scenario	CHPS_1-4	BRAD_1-8

Table 3-1: TEST RUN MATRIX

We were also able to run some other miscellaneous trials, including speed comparisons over an especially hilly route, and two short offensive excursions, in order to gain insight into how to improve the Quick Look Study.

3.2.9

STARTEX and ENDEX Conditions

Table 3-2 presents STARTEX and ENDEX conditions for the test run matrix listed above:

Phase	STARTEX	ENDEX
High Speed Route March	Scout Platoon Ordered to Move Out	ModSAF Reports End of Mission
Cross Country	Scout Platoon Ordered to Move Out	ModSAF Reports End of Mission
Defensive Scenario	BLUFOR on BP1, and OPFOR Ordered to Move Out, or BLUFOR on BP2, and OPFOR Ordered to Move Out	BLUFOR Combat Ineffective (< 3 undamaged vehicles), or First OPFOR vehicle reaches the end of the attack route, vicinity BP-2.

Table 3-2: STARTEX AND ENDEX CONDITONS

Note that there were two STARTEX conditions for the Defensive Scenario. The first condition was used for all CHPS runs and four Bradley runs (BRAD_1-4.) These conditions assumed that even though the Bradleys took 10 minutes longer getting into position, they still had adequate time to reach BP1. The second STARTEX condition applied to Bradley runs BRAD_5-8. In this case, the Bradleys were penalized for their slower speed, and began the battle from BP2.

4 Observations and Lessons Learned

4.1 CHPS Requirements Analysis Results

The panel of Subject Matter Experts provided information about Speed, Silent Operations and Silent Watch requirements. Table 4-1 presents the general consensus regarding speed requirements:

	Minimum	Desirable Sustained	Maximum Dash
Paved Roads	45 mph	60 mph	70 mph
Cross Country	15 mph	30 mph	**50 mph**
Up slopes (60%)	4 mph	6 mph	10 mph
Acceleration (0-60) Fwd AND **Reverse**	25 secs	20 secs	15 secs

NOTE: The early AAN ground concept vehicle's speed characteristics were 100 mph max and 75 mph sustaine for paved roads and 40 mph cross country. Initial games showed these top speeds to be not realistic/too fast. T next games will run using 50 mph max and 30 mph cross country speeds (Gene Baker
NOTE: Vehicles will almost always move as part of a unit under someone's command and control (in formatio

TABLE 4-1: SPEED REQUIREMENTS

There was not the same level of consensus in the area of silent operations (silent mobility and silent watch), primarily because it was an area that our Army had not had much experience with. Our dismounted infantry had much experience, but our mounted forces have never relied on stealth on the battlefield. In general, however, there was no great disagreement with the information in Table 4-2.

	How far away? (from enemy)	How fast? (max speed)	How far? (to travel)
4-ton RST-V	50 meters	30 mph	30 miles
15-ton Notional Vehicle	100 meters	20 mph	10 miles
40-ton Future Combat System	400 meters	20 mph	5 miles

NOTE: Our forces will almost always be operating as part of a unit, moving in a formation under someone's command and control.

TABLE 4-2: SILENT OPERATIONS REQUIREMENTS

In the area of silent watch, there was general agreement that an 8-12 hour

period of silence would provide about the right amount of operational flexibility for the ground commander, that it would cover most "quiet" interludes on the battlefield, and provide enough time for the necessary amount of crew rest. Silent watch was defined as the continuous use of all systems on the vehicle requiring power (e.g. comms, sensors, signature management, NBC overpressure, fire control, etc.) using only stored electric power.

4.2 ModSAF Quick Look Study Results

We collected three main types of data:

1) Time Data - Time Data include Route March and Time in Contact. Table 4-3 presents the average time in minutes that the CHPS and Bradley took to complete the route marches. Detailed data are included in Appendix D.

	Road March	Cross Country	Total
BRADLEY	12.5	22.5	35
CHPS	7.5	17.5	25

TABLE 4-3 ROUTE MARCH TIMES

Mean Time in Contact data are presented in Table 4-4. These data represent the average length of time between when BLUFOR first reported contact and when the run ended. Additional time data from the combat engagements are in Appendix E.

	CHPS 1-4	BRAD_1 - 4	BRAD_5 - 8
Mean Time (mins)	15	10	3

TABLE 4-4: MEAN TIME IN CONTACT

2) Combat Effectiveness Data - The DIS Test Suite provided the capability to log information regarding the exercises for post exercise analysis. Combat effectiveness data presented here include these data as well as manually collected observations made during the test runs. Table 4-5 shows the ENDEX criteria that were met for those sets of trials and the percentage of undamaged vehicles remaining at the end of the exercise.

	CHPS 1-4	BRAD_1 - 4	BRAD_5 - 8
ENDEX Condition			
- Combat Ineffective	2	4	4
- OPFOR End of Route	2	-	-
Percent Undamaged			
- OPFOR	36.1%	43.1%	55.6%
- BLUFOR	45.8%	12.5%	8.3%

TABLE 4-5: COMBAT EFFECTIVENESS DATA

The data used to derive these summaries is included at Appendix F. Summary engagement data are presented in Table 4-6. A more detailed look at engagement data is at Appendix G.

	Overall	Shots	Hits	Misses	% Hit
CHPS	BLUFOR	179	49	130	27.4%
	OPFOR	107	31	76	29.0%
BRADLEY	BLUFOR	88	71	17	80.7%
	OPFOR	136	37	99	27.2%

TABLE 4-6: SUMMARY ENGAGEMENT DATA

3) Observations - We took extensive notes regarding the conduct and outcome of the exercise. Due to the qualitative nature of this information, we will incorporate these observations into the Discussion section.

5 Conclusion

Recall that the specific goals of the Quick Look Study were to:

- Examine the sensitivity of ModSAF model behavior to differences in vehicle performance characteristics
- Examine the sensitivity of selected mission and vehicle performance measures to differences in vehicle performance characteristics
- Examine the adequacy of selected virtual combat scenarios for possible future studies
- Examine the value of the currently proposed CHPS mission profile and ModSAF's capability to execute it
- Gain insight regarding capabilities of a CHPS-powered vehicle relative to incumbent systems (specifically the M3A3 Bradley Scout vehicle) in executing selected missions.

This section will discuss these issues in detail. It is important to note that these are the results of a pilot study with notional changes to the models and a minimal number of runs. The results can be considered preliminary at best, but do indicate that the ModSAF model can provide important information for the development of the CHPS.

5.1 ModSAF Sensitivity

The question here is whether or not the changes in the underlying ModSAF vehicle parameters would result in observable differences in model behavior on the battlefield and in the results of the engagements fought. These issues include the following factors:

- Speed - Does the model reflect the changes in vehicle speed and what difference does speed make in a battlefield scenario? CHPS units took an average of 10 minutes less time to get to BP-1 than the Bradleys did. It is important to note that the time differential was not simply the result of a road race between individual vehicles on a flat highway, but the difference between two units making tactical movements over varied terrain, that included fords, hills, and forested areas. Often, the speed of an individual CHPS vehicle was governed by the need to keep in formation with other members of the platoon. Nevertheless, the importance of getting to a superior fighting position due to the time differential clearly shows in the comparison between survivability and lethality data. When the Bradleys were allowed to begin the battle on BP1 (BRAD_1-4) , they survived longer, and killed more OPFOR vehicles than they did in (BRAD_5-8) where they were penalized for the 10 minute differential.

- Vulnerability - The scenario placed a lot of stress on BLUFOR units. Generally, a unit of this size would seek to avoid a direct fire engagement with two Motorized Rifle Companies unless forced to fight. Despite this, the CHPS unit remained combat effective for 2 out of 4 runs, while the Bradley units never made it through to the end of the run. Anecdotally, this appeared due to a combination of the increased "armor" protection and reduced detectability of the CHPS vehicles. While the CHPS were initially detected at about the same time as the Bradleys, they routinely were able to break contact during the movement to BP2, while the Bradleys were not. This made the Bradleys extremely vulnerable at this critical time.
- Accuracy - Hit rates for OPFOR and CHPS vehicles averaged about 28%, while the Bradleys averaged 80%. This might seem low for the OPFOR and CHPS, but actually reflects current unclassified Army Materiel Sciences Activity data for a combat (vice target range) environment. Two questions that must be resolved in this case: 1) are these rates representative of hit rates expected for the scenario timeframe, and 2) why is the Bradley hit rate so high? Even if the hit rate for the Bradleys is unreasonabley high, it does not work against the purpose of this study. The relatively high hit rate of the Bradleys merely provides a more conservative baseline with which to compare CHPS vehicle performance: despite the potentially exaggerated difference in accuracy, the CHPS vehicles still survived longer, and killed more enemy than the Bradley.

Overall, we were able to observe the impact of differences in the vehicle parameters in exercise outcome.

5.2 Performance Measures

The time and location of the exercise limited the kind and amount of performance measures we were able to provide for this study. The DIS Test Suite provides only a limited capability to analyze data that it logs, forcing us to perform extensive manual manipulation of the data to provide the information listed in the Appendixes. While these measures provide an adequate, high-level view of the exercise, more detail is desirable. A core DIS facility, such as the Mounted Warfare Test Bed at Ft Knox, offers a more robust set of logging and analysis tools that will permit the automated generation of more detailed measures. These tools can also provide an additional analysis of the Quick Look data, if requested.

5.3 Combat Scenarios

Original plans called for a comparison of offensive, defensive, and silent mobility scenarios. Due to time and budget constraints, this was reduced to only the defensive scenario. This scenario included road and cross country movement as well as a high stress combat engagement. It was successful in revealing differences between the two vehicles. and should be considered for any subsequent runs. We also ran excursions to examine offensive and high demand cross county runs. While the offensive scenario looked like it could provide

interesting information about the impact of speed and stealth on combat operations, the high demand cross country movement did not. We were unable to examine a scenario that simulated silent mobility characteristics due to current limitations in the ModSAF model.

5.4 Mission Profile

The Table 5-1 compares features of the Quick Look scenario with that of the proposed Mission Profile:

Mission Profile Event	Achieved in Quick Look Study
1. Road March	X
2. Cross Country	X
3. Silent Cross Country	
4. Engagement	X
5. Swim	

TABLE 0-1: MISSION PROFILE COMPARISON

We were able to model the speeds and distances described in the Cross Country and Road March segments. We performed all of the engagement activities except use of the high powered laser. We also noted that the ratio of Road March to Cross Country movement listed in the Mission Profile may reflect too high a proportion of time on the Road March for a combat situation.

5.5 CHPS Capabilities

Even though the Quick Look study only provided an initial approximation of CHPS performance capabilities, it appears that even with a restricted set of enhancements, the CHPS provides a more capable platform for Army After Next missions than the Bradley A3. The combination of speed, stealth, survivability, and lethality allowed the CHPS to get into better battle positions, last longer in the face of enemy fire, and inflict more damage to enemy forces even with a weapon systems model that heavily favored the Bradley in terms of lethality and accuracy. The ability of the CHPS to remain concealed longer and break contact with the enemy once engaged suggests that its reduced signature will enhance its ability to accomplish combat missions. The bottom line is that while the Bradley equipped forces were never able to complete the exercise in a combat effective state, the CHPS did so 2 out of 4 times.

6 Recommendations

There are two categories of recommendations. Vehicle characteristics recommendations include:

- Maximum Speed - maximum speed requirements for the notional CHPS vehicle should be revised to reflect the consensus of the expert panel canvassed in this study. Speed is an essential aspect of all Army After Next discussions, but the experts contend that there is a limit to speeds vehicles need to attain, which is driven by crew safety, crew abilities to react appropriately, and crew abilities to execute their normal duties and skills. In addition, although it is desirable that individual vehicles be able to perform great dash speed maneuvers, in nearly every instance, the vehicles will be employed as part of a larger unit (at least two of them working together), operating in some kind of formation, under the control of a junior leader (sergeant or lieutenant). Seventy miles per hour on hard, paved roads (like German autobahns or American interstate highways) is probably appropriate. However, fifty miles per hour on most cross country terrain would be considered extremely fast - formations at faster speeds would probably be unsafe for many of the participants and be very difficult to control.
- Acceleration - Any acceleration requirement (e.g. 0-60 mph in 15 seconds) should include movement in reverse in addition to movement forward.
- Silent Operations - Silent operations and silent watch should be studied in much greater detail. Our Army has little or no experience with silent mobility and there is little consensus on exactly how we would employ vehicles with this capability (even though it is assumed by all to be a great advantage).
- Mission Profiles - Mission profiles for the CHPS notional vehicle need to be reviewed to ensure that they are realistic portrayals of combat scenarios. Running an individual vehicle through a course to stress all parts of the power system is a good technique to assess maximum loads, but may or may not be realistic enough to drive design specifications.

We recommend additional ModSAF simulation studies to assess the potential combat effectiveness of a CHPS notional vehicle withselected performance characteristics. Features of these studies should include:

- Larger and More Complex Engagements - This pilot study included only a platoon of friendly forces going against (up to) two motorized rifle companies, with only some basic artillery in support of both sides. Future studies should involve a BLUFOR company-sized unit, and should include as many other combat factors as possible (e.g. helicopters, air support, air defense, engineer play, etc.) to further ensure that any assessment of combat effectiveness is able to be made within the context of a more complete battlespace.
- Longer Scenarios - Although it is not necessary to run scenarios over the length of time required to assess the anticipated logistical advantages of the CHPS vehicles, longer

combat scenarios ought to be run and evaluated to place additional stress on the units, vehicles and crews (e.g. hours rather than minutes).

- Both Offensive and Defensive Scenarios - This study had time only to use a simplistic and short defensive scenario. More maneuverability, detectability, lethality, and survivability data could be gained with good, long offensive missions (including movements to contact).

- Silent Operations - A new study should include scenarios in which the CHPS vehicles can use their silent operations and silent watch capability. Realistic scenarios can be drawn up which would place the friendly vehicles in close proximity to the enemy and require silent movement and activities to be successful.

- More Varied Terrain - This study conveniently used a readily available terrain database of the training area near Ft. Knox, KY. New studies ought to provide several other terrain alternatives, such as the desert-type terrain at the National Training Center in California, the moderately rolling terrain of Central Europe, and the mountainous terrain of Korea or Bosnia. The CHPS vehicles ought to be challenged more in terms of gradability and trafficability to better measure mobility and maneuverability, and any subsequent combat effectiveness advantages.

- Enhanced CHPS Model - This pilot study modified selected performance characteristics of the already existing ModSAF Bradley M3A3 to "create" a CHPS vehicle. This "rough approximation", albeit good enough for this small pilot test, could not capture all of the features that can be included in a model specifically added to ModSAF for the CHPS vehicle.

- Silent Operations - This sturdy did not permit an opportunity to modify the detectability parameters of ModSAF to allow the possibility of silent operations by the CHPS vehicles. The current parameters do not take "quiet" into account when determining under what circumstances a vehicle can be detected by what systems at what ranges. The detectability parameters can be modified by a realistic and reasonable factor to allow for silent operation and silent watch.

- More Extensive List of Measures - This would provide more detailed analysis of more of the "ilities" - maneuverability, lethality, survivability, detectability, etc. One example would be to capture "bullseye" data. During the pilot study, we were able to discern if a vehicle was hit by an enemy round of ammunition. Bullseye data would tell us exactly where on the vehicle all of the rounds struck and when. This data is important to the engineers developing the electric armor, in that they want to know where and with what frequency they can expect enemy rounds to strike this defensive system.

- Mounted Warfare Test Bed (MWTB) at Fort Knox, KY - The Pilot Study was done at the Lockheed-Martin facility in Orlando, FL. However, the MWTB is a better facility, with more qualified ModSAF operators with armored vehicle experience, and more experienced engineers and technicians for this kind of research and development analysis.

In addition, Fort Knox is the home of Armor and the best place to discuss, work on and analyze armored vehicle requirements.

7 Points of Contact

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STRICOM

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8 Acronym List

AAR	After Action Review
ADST	Advanced Distributed Simulation Technology
BCIS	Battlefield Combat Identification System
BFV	Bradley Fighting Vehicle
BLEP	Battle Lab Experiment Plan
BLUFOR	Blue Forces
C2	Command and Control
C2TD	Command and Control Tactical Display
CDF	Core DIS Facility
CDRL	Contract Data Requirements List
CECOM	Communications & Electronics Command
CHPS	Combat Hybrid Power Systems
CIG	Computer Image Generator

CVSD	Continuous Variable Slope Delta
DDL	Digital Data Link
DO	Delivery Order
DIS	Distributed Interactive Simulation
E-BCIS	Enhanced Battlefield Combat Identification System
EPLRS	Enhanced Position Location Reporting System
EXFOR	Experimental Force
FPE III	Force Protection Experiment III
FRAGO	Fragmentary Order
FTP	File Transfer Protocol
GFE	Government Furnished Equipment
GPS	Global Positioning System
HDCD	Hardware Design Configuration and Document
HECV	Hybrid Electric Combat Vehicle
H/W	Hardware
IDS	Integrated Defense System
INC	Internet Controller
I/O	Input/Output
LAN	Local Area Network
LMC	Lockheed Martin Corporation
LMSG	Lockheed Martin Service Group
LRF	Laser Range Finder
M1Ax	Abrams Main Battle Tank ("x" = variant)
MBT	Main Battle Tank
Mini-FAS	Mini Feasibility Analysis Study
ModSAF	Modular Semi-Automated Forces
MMBL	Mounted Maneuver Battle Lab
MMW	Millimeter-Wave
MWTB	Mounted Warfare Test Bed

OC	Observer Controller
OPFOR	Opposing Forces
OPORD	Operations Order
OMI	Optimetrics, Inc
OS	Operating System
OSF	Operational Support Facility
PC	Personnel Computer
PDU	Protocol Data Unit
PLGR	Precision Lightweight GPS Receiver
PM	Program Manager
POC	Point of Contact
PPP	Point-To-Point Protocol
PVD	Plan View Display
RAM	Random Access Memory
RIU	Radio Interface Unit
RP	Role Player
SAF	Semi-Automated Forces
SCO	Santa Cruz Operating System
SEIT	Systems Engineering Integration Team
SGI	Silicon Graphics Industries
SIMNET	Simulation Network
SINCGARS	Single Channel Ground and Airborne Radio System
SME	Subject Matter Expert
SOW	Statement of Work
SRE	SINCGARS Radio Emulator
SRM	SINCGARS Radio Model
STRICOM	(US Army) Simulation Training and Instrumentation Command
TACOM	Tank Automotive and Armaments Command

TARDEC	Tank Automotive and Armaments Command Research Development and Engineering Center
TC	Tank Commander
TECO	Test and Evaluation Coordination Office
TF	Task Force
TIM	Tactical Internet Model
TIM	Technical Interchange Meeting
TRR	Test Readiness Review
TTP	Tactics, Techniques, and Procedures
UDP	User Data Protocol
VDD	Version Description Document
VMF	Variable Message Format
VIP	Very Important Person

Appendix A – Vehicle Characteristics

Issue	Class	Datum	Bradley	CHPS	BM
Trafficability	Soil Road	Max Speed	65.18 kph	113.0 kph	65.1
		Max Acceleration	1.42 m/s/s	1.79 m/s/s	1.42
		Max Deceleration	4.27 m/s/s	8.0 m/s/s	8.0
		Max Turn	30 degs/s	30 degs/s	30 d
		Max Climb	45 deg	60 deg	45 d
	Soil RCI250	Max Speed	65.18 kph	113.0 kph	65.1
		Max Acceleration	1.42 m/s/s	1.79 m/s/s	1.42
		Max Deceleration	4.27 m/s/s	8.0 m/s/s	8.0
		Max Turn	30 degs/s	30 degs/s	30 d
		Max Climb	45 deg	60 deg	45 d
	Soil RCI050	Max Speed	43.45 kph	90.0 kph	43.4
		Max Acceleration	0.99 m/s/s	1.79 m/s/s	.099
		Max Deceleration	4.27 m/s/s	8.0 m/s/s	8.0
		Max Turn	30 degs/s	30 degs/s	30 d
		Max Climb	45 deg	60 deg	45 d
	Soil Shallow Water	Max Speed	21.73 kph	21.73 kph	21.7
		Max Acceleration	0.44 m/s/s	0.44 m/s/s	0.44
		Max Deceleration	4.27 m/s/s	4.27 m/s/s	4.27
		Max Turn	30 degs/s	30 degs/s	30 d
		Max Climb	45 deg	45 deg	45 d
	Soil Deep Water	Max Speed	0.00 kph	0.00 kph	0.00
		Max Acceleration	0.400 m/s/s	0.400 m/s/s	0.40
		Max Deceleration	4.27 m/s/s	4.27 m/s/s	4.27
		Max Turn	30 degs/s	30 degs/s	Stan
		Max Climb	45 deg	45 deg	Stan
Issue	Class	Datum	Bradley	CHPS	BM
Weapons	TOW2B AT Missile	Min Range	0		
		Max Range	3750		
		Rate	5		
		Round Velocity	301.483		
	25 MM HE	Min Range	0		
		Max Range	2800		
		Rate	200		
		Round Velocity	1100		
	25 MM SABOT	Min Range	0		
		Max Range	2800		
		Rate	200		
		Round Velocity	1100		

	M240 - Coax Machine Gun	Min Range	0	0	
		Max Range	400	400	
		Rate	700	700	
		Round Velocity	838	838	
	75MM ETC Gun	Min Range		0	
		Max Range		3000	
		Rate		20	
		Round Velocity		1500	
	Stingray	Min Range		N/A	
		Max Range		N/A	
		Rate		N/A	
		Round Velocity		N/A	
Issue	Class	Datum	Bradley	CHPS	BM
	30 mm HE	Min Range			
		Max Range			
		Rate			
		Round Velocity			
	30 mm SABOT	Min Range			
		Max Range			
		Rate			
		Round Velocity			
	7.62x54R Coax Machine Gun	Min Range			
		Max Range			
		Rate			
		Round Velocity			
	Spandrel AT-5 Missile	Min Range			
		Max Range			
		Rate			
		Round Velocity			
Logistics	Fuel		662.5 liters	662.5 liters	1,89
	25MM HE		625 rounds	-	
	25MM SABOT		325 rounds	-	
	M240		2,340 rounds	2,340 rounds	
	TOW2B		12 Rounds	-	
	75 MM ETC Gun		-	50 rounds	
	Stingray			Unlimited	
	30 MM HE				340
Issue	Class	Datum	Bradley	CHPS	BM
	30 MM SABOT				160
	7.62x54R Coax Machine Gun				2,00
	Spandrel AT-5				4 ro

Appendix B – Probability of Detection Data

Columns:

Rge: Range (m)
Det: P-infinity for Detection
Cla: P-infinity for Classification
Rec: P-infinity for Recognition
Id: P-infinity for Identification
Time: Average Time of Acquisition (sec)

Rge	Det	Cla	Rec	Id	Time
100	1.000	1.000	1.000	1.000	1.0
500	1.000	1.000	0.996	0.849	1.0
1000	1.000	0.988	.0735	.0214	1.0
1500	0.994	0.810	0.273	0.050	1.6
2000	0.924	0.441	0.090	0.015	2.6
2500	0.605	0.146	0.025	0.004	3.9
3000	0.220	0.039	0.007	0.001	10.7
3500	0.067	0.011	0.002	0.000	35.0
4000	0.021	0.004	0.001	0.000	111.3

Appendix C- Route March Times (Mins)

Run ID	**BRADEF1**	**BRADEF2**	**BRADRM1**	**BRADRM2**	**BRADRM3**
STARTEX	0817	1512	1445	0812	0843
END_RM_1	0831	1523	1455	0829	0853
RM 1 TIME	0014	0011	0010	0017	0010
Run ID	**CHPSRM1**	**CHPSRM2**	**CHPSRM3**	**CHPSRM4**	**CHPSRM5**
STARTEX	0829	0900	0909	0919	0948
END_RM_1	0838	0907	0917	0926	0955
RM 1 TIME	0009	0007	0008	0007	0007
Run ID	**BRADEF 1**	**BRADEF 2**	**BRADRM1**	**BRADRM2**	**BRADRM3**
STARTEX	0831	1523	1119	1142	1322
END_RM_2	0853	1544	1141	1204	1347
RM 2 TIME	0022	0021	0022	0022	0025
Run ID	**CHPSRM1**	**CHPSRM2**	**CHPSRM3**	**CHPSRM4**	**CHPSRM5**
STARTEX	1024	1043	1056	1301	1353
END_RM_2	1041	1100	1114	1320	1410
RM 2 TIME	0017	0017	0018	0019	0017

Notes: 1) STARTEX and END times are wall clock to nearest minute. RM times are in minutes.

Appendix D- Battle Times

RUN	RUN_ID	STARTEX	RED_1	RED_2	BLUECONT	REDCONT	WDRAW	ON_BP_2
1	CHPS_1	0748	0748	0752	0752	0753	0758	0804
4	CHPS_2	0920	0920	0921	0922	0924	0928	
6	CHPS_3	1004	1005	1005	1006	1007	1012	1018
7	CHPS_4	1036	1036	1037	1038	1040	1045	1050
2	BRAD_1	0820	0820	0824	0822	0822	0831	
3	BRAD_2	0841	0841	0841	0843	0843	0849	
5	BRAD_3	0940	0940	0941	0942	0942	0948	
8	BRAD_4	1058	1058	1059	1100	1101	1105	
9	BRAD_5	1308	1308	1308	1310	1310		1310
10	BRAD_6	1318	1318	1318	1320	1320		1320
11	BRAD_7	1329	1329	1329	1331	1331		1331
12	BRAD_8	1341	1341	1341	1342	1342		1342

Notes: 1) Fields:

RUN	Order in which trials were run
RUN_ID	Run Identifier: CHPS were CHPS runs, BRAD_1 - BRAD_4 allowed the Bradleys to s BRAD_5 - BRAD_8 started the Bradleys at Battle Position 2
STARTEX	Starting time of the exercise
RED_1	Time when first OPFOR unit moved out
RED_2	Time when second OPFOR unit moved out
BLUECONT	Time when BLUFOR unit first detected OPFOR unit
REDCONT	Time when OPFOR unit first detected BLUFOR unit
WITHDRAW	Time when BLUFOR Commander gave order to withdraw to Battle Position 2
ON_BP_2	Time when BLUFOR unit was in place on Battle Position 2
ENDEX	Time when scenario met one of the completion criteria
In Contact	Time between BLUECONT and ENDEX
Avg.	Average time in contact for each set of 4 trials

2) All times are clock time to nearest minute except In Contact and Avg. which are time in minutes.

Appendix E – Damage Data

Run Number	Run ID	Unit	Undamaged	Catastrophic	Mobility
1	CHPS_1	CHPS	5	1	
	1ST	T72	3		
		BMP		1	2
		BMP		2	1
	2ND	T72	3		
		BMP	3		
		BMP	3		
	ENDEX	End of Route			
2	BRAD_1	BRAD	2	1	3
	1ST	T72		3	
		BMP		3	
		BMP		3	
	2ND	T72	3		
		BMP	3		
		BMP	2	1	
	ENDEX	Blue ineffective			

Run Number	Run ID	Unit	Undamaged	Catastrophic	Mobility
3	BRAD_2	BRAD	2	3	1
	1ST	T72	2	1	
		BMP	1	2	
		BMP	2	1	
	2ND	T72	3		
		BMP	3		
		BMP	1	1	1
	ENDEX	BLUE Ineffective			
4	CHPS_2	CHPS	2	4	
	1ST	T72		2	
		BMP	2		1
		BMP	3		
	2ND	T72	2	1	
		BMP	1		2
		BMP	1		2
	ENDEX	Blue Ineffective			

Run Number	Run ID	Unit	Undamaged	Catastrophic	Mobility
5	BRAD_3	BRAD	2	3	1
	1ST	T72		3	
		BMP	1		2
		BMP		3	
	2ND	T72	3		
		BMP	3		
		BMP	3		
	ENDEX	Blue Ineffective			
6	CHPS_3	CHPS	3	2	1
	1ST	T72		3	
		BMP		2	1
		BMP	1		2
	2ND	T72	1	1	1
		BMP	3		
		BMP	3		
	ENDEX	End of route			

Run Number	Run ID	Unit	Undamaged	Catastrophic	Mobility
7	CHPS_4	CHPS	2	3	
	1ST	T72		1	2
		BMP	2		1
		BMP	1		2
	2ND	T72	3		
		BMP	3		
		BMP	3		
	ENDEX	Blue ineffective			
8	BRAD_4	BRAD	2	4	
	1ST	T72		1	2
		BMP	1	2	
		BMP	1	2	
	2ND	T72	2	1	
		BMP		2	1
		BMP	3		
	ENDEX	Blue Ineffective			
	NOTES				

Run Number	Run ID	Unit	Undamaged	Catastrophic	Mobility
9	BRAD_5	BRAD	1	3	2
	1ST	T72	3		
		BMP	2		1
		BMP	2		
	2ND	T72	3		
		BMP		3	
		BMP	3		
	ENDEX	BLUE Ineffective			
10	BRAD_6	BRAD	2	3	1
	1ST	T72	1	2	
		BMP	3		
		BMP		3	
	2ND	T72	2	1	
		BMP	2	1	
		BMP	3		
	ENDEX	BLUE Ineffective			

Run Number	Run ID	Unit	Undamaged	Catastrophic	Mobility
11	BRAD_7	BRAD	2	3	1
	1ST	T72	2	1	
		BMP		2	
		BMP	3		
	2ND	T72	2		1
		BMP	1	2	
		BMP	2		1
	ENDEX	Blue Ineffective			
12	BRAD_8	BRAD	2	2	2
	1ST	T72	1	1	1
		BMP	3		
		BMP	2		1
	2ND	T72		2	1
		BMP	3		
		BMP	3		
	ENDEX	Blue Ineffective			

Kill Summaries

Run	Kill Type	T72	BMP	CHPS	BRADLEY	
CHPS_1-4 Runs	Catastrophic	8	5	10		
	Firepower	3	13	2		
	Mobility	3	14	1		
	Total	14	32	13		
Brad_1-4 Runs	Catastrophic	9	20		11	
	Firepower	2	4		5	
	Mobility	2	4		5	
	Total	13	28		21	
Brad_5-8 Runs	Catastrophic	7	11		11	
	Firepower	3	5		5	
	Mobility	3	3		6	
	Total	13	19		22	

Appendix F – Firing Data

Blue Vehicle

Run	Vehicle #	Shots	Hits	Misses	HT-AT5	HT-AT8	HT Sabot	HT HEAT	Notes
CHPS_1	1001	26	12	14	-	-	1	-	
	1002	26	14	12	-	-	-	-	
	1005	3	1	2	-	-	-	-	
	1006	7	1	6	-	-	-	-	
	1008	-	-	-	-	-	-	-	
	1009	3	0	3	5	-	2	-	
CHPS_2	1010	2	-	2	-	-	-	-	Incomplete
	1011	-	-	-	-	-	-	-	
	1012	-	-	-	1	-	-	-	
	1013	-	-	-	1	-	-	-	
	1014	-	-	-	-	-	-	-	
	1015	-	-	-	-	-	-	-	
CHPS_3	1147	10	3	7	1	-	1	-	
	1149	21	1	20	4	-	-	-	
	1159	0	0	0	-	1	-	-	
	1160	5	1	4	2	2	-	-	
	1161	24	4	20	-	-	-	-	
	1162	29	7	22	-	-	-	-	

Notes:

1. HT means hit taken by that type of munition
2. These data not available for BRAD_5-8 runs.

Run	Vehicle #	Shots	Hits	Misses	HT-AT5	HT-AT8	HT Sabot	HT HEAT	Notes
CHPS_4	1167	-	-	-	2	-	-	-	
	1168	-	-	-	4	-	-	-	

	1169	-	-	-	-	-	-	-
	1170	2	0	2	1	-	-	-
	1171	13	3	10	-	-	-	-
	1172	8	2	6	1	-	-	-
BRAD_1	1029	-	-	-	-	-	-	-
	1035	7	6	1	4	-	-	-
	1039	-	-	-	1	-	-	-
	1044	2	2	0	1	-	-	-
	1049	12	11	1	1	2	-	-
	1055	2	1	1	-	-	-	-
BRAD_2	1164	5	5	-	1	-	-	-
	1171	2	1	1	2	-	-	-
	1182	5	2	3	1	-	1	-
	1187	3	3	0	1	-	-	-
	1196	1	1	0	-	-	-	-
	1200	4	2	2	1	-	-	-

Run	Vehicle #	Shots	Hits	Misses	HT-AT5	HT-AT8	HT Sabot	HT HEAT	Notes
BRAD_3	1068	1	1	0	-	1	-	-	
	1074	3	2	1	-	0	-	-	
	1077	6	6	0	-	1	-	-	
	1087	4	3	1	-	1	3	-	
	1090	4	0	4	-	-	2	-	
	1093	6	6	0	-	4	3	2	
BRAD_4	1201	2	2	0	-	-	1	-	
	1205	4	4	0	1	-	-	-	
	1214	2	2	0	-	-	-	-	
	1217	3	3	0	2	-	-	-	
	1220	3	3	0	1	-	-	-	
	1223	7	5	2	3	-	-	-	

Red Vehicle

Run	Vehicle #	Shots	Hits	Misses	Notes
CHPS_1	1054	4	1	3	
	1004	7	0	7	
	1051	4	1	3	
	1065	4	2	2	
	1014	4	2	2	
	1061	4	0	4	
	1007	4	0	4	
	1034	1	0	1	
	1057	4	2	2	
CHPS_2					Incomplete Data Collection
CHPS_3	1383	16	3	13	
	1320	4	2	2	
	1312	14	3	11	
	1357	4	3	1	
	1334	7	0	7	
	1347	7	0	7	
	1304	2	1	1	
	1324	5	2	3	
	1351	3	1	2	

Run	Vehicle #	Shots	Hits	Misses
CHPS_4	1485	4	4	0
	1440	1	1	0
	1424	1	1	0
	1458	3	2	1
BRAD_1	1181	4	4	-
	1129	5	2	3
	1147	4	2	-
	1121	4	1	3
	1135	4	0	4
	1132	2	0	2
BRAD_2	1215	6	3	-
	1288	1	1	0
	1225	11	1	10
	1228	3	0	3
	1270	1	1	0
	1222	1	0	1
	1291	1	1	0

Run	Vehicle #	Shots	Hits	Misses
BRAD_3	1230	1	0	1
	1290	13	5	8
	1220	7	1	6
	1204	5	4	1
	1285	16	4	12
	1261	3	0	3
	1210	10	3	7
	1236	1	0	1
BRAD_4	1506	13	2	11
	1513	7	0	7
	1581	6	1	5
	1574	5	0	5
	1493	1	1	0
	1513	1	0	1
	1551	5	0	5
	1496	3	2	1
	1523	2	1	1
	1517	2	1	1