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**RISK MANAGEMENT AND SIMULATION BASED LIVE FIRE TEST
AND EVALUATION IN THE PERFORMANCE BASED DEFENSE
BUSINESS ENVIRONMENT**

BY

**LIEUTENANT COLONEL R. MARK BROWN
SENIOR SERVICE COLLEGE FELLOW, U.S. ARMY
THE UNIVERSITY OF TEXAS AT AUSTIN**

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ENVIRONMENT**

by

Lieutenant Colonel R. Mark Brown

Dr. Jerry Davis

Project Advisor

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ABSTRACT

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The objective of this analysis is to reduce the policy and management process costs of Congressionally mandated Live Fire Test and Evaluation procedures in the new Performance Based Defense Acquisition environment. The service and acquisition program independent Live Fire Test and Evaluation Community has not fully recognized the changing defense acquisition business environment and modified policy and business processes to account for the changes. It is not the purpose of this paper to dispute the need for live fire test and evaluation, which is and will remain, a key component of the defense acquisition process in order to ensure combat system survivability and/or lethality. This paper explores the historical background, features and resourcing of DOD's Life Fire Test and Evaluation Program. Further, the paper examines how simulation and risk management might be integrated to ensure user confidence in weapon systems, while seeking a more effective and affordable process. The paper makes four recommendations to that end.

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Simulation and Risk Management Based Live Fire Test and Evaluation

I. Introduction:

The fall of the Berlin Wall in 1989 and the subsequent dissolution of most of the world's Communist states over the following few years was a watershed event for the US Department of Defense and all professionals involved in the theorizing, planning, and operations of national defense. In a very short time span, defense professional thought has had to transfer from planning and operating in a relative balance of power stasis to one of relative random events and chaos. There have been many emerging results of this change in virtually every aspect of national defense.

Notably, defense intellectuals have theorized about a broad array of national defense changes categorized as the Revolution in Military Affairs. For the purposes of this paper, the definition of the Revolution of Military Affairs will be simply the changes in military affairs brought on by the advent of the Information Age. These changes are characterized by features such as short to no notice joint/combined maneuver warfare of smaller, more rapidly maneuverable and deployable forces. These forces possess near real time situational awareness of friendly forces, enemy forces, terrain, and weather and are staffed with smaller numbers of personnel equipped with high

technology equipment for intelligence, command, control, communications and logistics.¹ These forces are armed with precision or “brilliant” weapons for engaging the enemy.²

The initial transition from industrial age warfare to information age warfare began during the Viet Nam War and accelerated through the Persian Gulf War and is still accelerating.³ To complete the transition, forces will have to be re-equipped with information age technologies as today’s forces are still largely equipped with industrial age equipment. To make the transition envisioned by the Revolution in Military Affairs affordable, and therefore possible, there will have to be a Revolution in Business Affairs.⁴ This revolution is largely under way, and has been, since the Clinton administration came to office in 1992. The Revolution in Business Affairs is the revolution that impacts the “Business of Defense” as opposed to the operations and conduct of armed conflict. The Revolution in Business Affairs includes several sub-aspects including:

- Re-engineering Defense Transportation.
- Acquisition Reform.
- Re-engineering Defense Finance.

¹ The Honorable Robert M. Walker and General Dennis J. Reimer, “*United States Army Posture Statement FY99*”, February 1998, pp. 23-58.

² General John M. Shalikashvili, “*Joint Vision 2010*”, pp. 11-26 and General Dennis J. Reimer, “*Army Vision 2010*”, pp. 10-17.

³ Alvin and Heidi Toffler, *War and Anti War: Making Sense of Today’s Global Chaos*, pp. 73-99.

⁴ The Honorable Robert M. Walker and General Dennis J. Reimer, p. 59.

- A Revolution in Logistics.
- Others.

The Revolution in Logistics, or the transition from mass quantity supply of the battlefield under a "push" concept to "focused" logistics, is characterized by supplying precise unit needs at a specific time and is enabled by information age technologies. Examples of such technologies include Total Asset Visibility and In Transit Visibility which provide "Just in Time" inventory to the battlefield. The Revolution in Logistics also features supply delivered by premium transportation, such as Federal Express or United Parcel Service and contractor provided combat systems support, such as the Army's Apache Helicopter Prime Vendor Support contractor provided maintenance concept. These changes are impacting all aspects of logistics including all phases of supply, maintenance, transportation, and materiel acquisition.

For the purposes of this paper, materiel acquisition will be considered a sub-component of logistics and will include all aspects of concept development, developmental research beyond the pure research level, test and evaluation (developmental, operational, and live fire), production development, production, deployment, operations and support, and disposal. Information age technologies have been impacting all aspects of material acquisition for decades.

The Revolution in Logistics impact on the materiel acquisition process started with the invention of the micro chip and sped up with the advent of improved computing power and speed and improved software capabilities such as computer aided design and manufacturing capabilities. The speed of the change in materiel acquisition is progressing faster still, with the maturation of simulations, including live, virtual and constructive simulations. This process is essentially known as Simulation Based Acquisition.⁵ Anything short of actual warfare has been said to be simulation, but for the purposes of our discussion, we will discuss Simulation Based Acquisition as employing three levels of simulation.

- Live Simulation - including engagements among actual military forces and equipment with simulated weapons effects.
- Virtual simulation - comprising interactions among manned simulators of weapons platforms, operating in wholly synthetic computer generated environments
- Constructive simulation - mathematical models of combat including duels between weapons and ranging to wars among nations.

In the world of materiel acquisition business operations processes, the Revolution in Logistics has manifested itself in the form of a phenomenon known as Acquisition Reform. In ten years, Acquisition Reform has

⁵ LTC Michael V. R. Johnson, Sr., USA et al, *Simulation Based Acquisition*, pp. 1-1 to 1-4.

significantly changed almost every aspect of materiel acquisition business process operations including contracting, program management, engineering, developmental test, operational test, manufacturing, property administration, quality assurance, pricing, acquisition logistics and others not mentioned here.

Acquisition Reform is intellectually driven by the concept posed by the question, "What is the "value added" by this business process?" In other words, Acquisition Reform is a return on investment mentality that seeks at least the same amount of benefit returned, preferably much more, for resources expended. In fact, this attitude is not just permeating materiel acquisition but all aspects of resourcing in the federal budget process through the auspices of the National Performance Review and, of course, the Revolution in Business Affairs in the Department of Defense.

The intellectual concept of Acquisition Reform has transformed the Defense Department's materiel acquisition process from a "Risk Avoidance" based process to a "Risk Managed" based process primarily for reasons of affordability. However, study after study also made it clear that under a risk avoidance based system, risk still could not be avoided in the extremely complex defense acquisition process. Thus, the resources expended in avoiding risk were seen as not providing a commensurate return on investment. Therefore a key idea became to manage the risks so that when failure inevitably occurs, even as it does under risk avoidance, the failure

comes at an acceptable price and orders of magnitude greater benefits will be obtained elsewhere in the materiel acquisition business process. The mentality change was expected to yield better combat materiel systems, faster and at less expense to the national treasure.

Usually, "What is the "value added"?", is a very difficult question to answer involving very difficult relationships to demonstrate, if they can even be demonstrated. Many attempts are being made across the Department of Defense such as; the Defense Capital Working Fund, Activity Based Costing, Unit Cost Management and others to explain the relationship between resources expended to benefit obtained. These efforts will continue as long as there is competitive tension for resources within the federal government at large and within the Department of Defense in particular.

The fight is on, and has been for some time, for every organization to "get competitive or die" in this environment. This environment was officially declared by Vice President Gore's Reinvention of Government Initiative which grew out of the National Performance Review. These efforts seek a government that works better and costs less. The reinvention efforts have been characterized by a Performance Based Business Environment. In this Performance Based Business Environment, all organizations are endeavoring to show the precise output of benefit for the resources expended. These relationships are usually tracked through performance metrics for key

business function outputs and internal business operations in the pursuit of effectiveness and efficiency.⁶ The implementing concepts may be more or less based on the Malcolm Baldrige Quality Assurance criteria, sometimes tailored and renamed to better align with specific mission organizations. Legislators, the Department of Defense and all service material acquisition organizations have been major players in these pursuits with one notable exception - the Live Fire Test & Evaluation Community.

The balance of this paper will attempt to explore why the live fire test & evaluation business process has largely been a non-participant in the Revolution in Business Affairs and Acquisition Reform and why the community may feel exempt. The paper will offer some theories concerning why the Live Fire Test and Evaluation Community should participate in Acquisition Reform and how that can occur. Finally some proposals will be given to stimulate future thought and action on the matter. To get to that point the paper will discuss the legislative and policy background of why we have live fire test and evaluation, how the live fire test and evaluation business process works, and how the new era in materiel acquisition is impacting that process, perhaps without even the knowledge of or understanding the impact by the players, and how the Live Fire Test and Evaluation Community can leverage the changes to remain relevant and affordable in the future.

⁶ LTC Dennis Drayer, USAF, "*PBBE - A Business Vision We Can Live With*", pp. 57-67.

This paper and recommendations may not be well received. Criticism is likely from the Live Fire Test and Evaluation Community because it suggests what may be perceived as change that threatens their business. Nothing could be further from the truth. Therefore, the reason for undertaking this investigation is in order to explain the paper's position in advance.

First, the author is not a player in the live fire test and evaluation process, but is an acquisition professional and interested in live fire test and evaluation process. The concept of destroying something to make it better is inherently fascinating. The process has been effective in the past. The objective is to keep it affordable, effective and relevant in the future.

On a superficial level live fire test and evaluation is a fundamentally good idea and has generally worked in the past - but the environment, particularly the resourcing environment, is rapidly changing. Still, almost any process can be made better. This paper will demonstrate a strong proponency of live fire test and evaluation, but in a different form .

Second, the author has been a benefactor of the live fire test and evaluation process as a career combat arms military officer. This paper takes the position that there is nothing more important than the welfare and survivability of our military personnel. To quote Sun Tzu,

“For to win one hundred victories in one hundred battles is not the acme of skill. To subdue the enemy without fighting is the acme of skill.”⁷

Short of that, an operation that does not incur any casualties is ideal. We have come close to that in recent years, especially in the Persian Gulf War and in our operations in the Balkans. We can't always expect this to be the case.

This paper is an unbiased look at the live fire test and evaluation process because the author of this paper is a fundamentally interested casual observer with no ax to grind. The author is not and never has been a program manager. Nor is he likely to be a program manager. In that respect, the author can't be accused of bias against the live fire test process by viewing it as adversarial. Further, the author is not a test and evaluation specialist. Nor is he ever to likely be one. So in that respect, he can't be accused of having a bias for the current live fire test process, worried about threats to personal vested interests.

As a soldier and former leader of some of our nation's best combat soldiers, the author only wants our combat systems to have maximum lethality, survivability, operational effectiveness and suitability. Live fire test and evaluation is a critical component of ensuring those qualities in the equipment we develop and procure. Therefore, this paper strongly supports the live fire test and evaluation concept and argues that it is a critical materiel business

⁷ Sun Tzu, *The Art of War*, p. 77.

process that can not be eliminated under any circumstances. That is not the same thing as saying that the process is not ripe for reform or change.

As an acquisition professional, the author seeks the combat readiness of our armed forces through the acquisition of the most capable and affordable equipment for the fewest possible dollars, or best value, so that those dollars may be better spent elsewhere within the Department of Defense and on the needs of the nation outside of the Department.

Therefore the changes that are affecting every other materiel acquisition process under Acquisition Reform must also affect the live fire test and evaluation process for it to remain relevant, effective and affordable. This paper will argue that the process is not currently relevant, effective and affordable. Worse yet, the author could not even identify any critical thinking going on about how to ensure relevancy, effectiveness and affordability happen in the live fire test and evaluation process, in spite of extensive research.

The appearance then, if not the reality, is that the Live Fire Test and Evaluation Community envision themselves as unique and therefore exempt from Acquisition Reform. Many communities have viewed themselves as “special” and unique and therefore exempt from change, yet many that had that view have since reformed.

In summation, this paper is written as an “outside the box” think piece intended to stimulate discussion among thinking professionals concerning a very interesting and critical topic and to motivate constructive change for the benefit of our nation’s warriors.

II. Background and History of Live Fire Test and Evaluation:

Live Fire Test and Evaluation is defined as a sub category of Test and Evaluation, specifically Operational Test and Evaluation, that tests and evaluates the realistic system survivability (or in the case of missiles and munitions the system lethality) of Department of Defense acquisition programs. This is usually accomplished by taking live shots at a system or with by system at realistic targets under expected combat conditions.

The proponents of the Department of Defense Live Fire Test and Evaluation Program market themselves as the conscience of the acquisition system.⁸ This is a worthy ideal. Why do we have live fire test and evaluation? We have it for good and valid reasons. The history of our nation’s armed forces is replete with examples of weapon systems that did not work in combat as designed or expected, to the detriment of our warriors. In World War II torpedoes failed to explode, jeopardizing submariners engaged in mortal combat with Japanese surface warfare units. Early in World War II, US tanks

⁸ James F. O’Byron, “*Overview of Live Fire Test and Evaluation*”, Fort Belvoir, VA, undated, slide 000035.

were powered by gasoline, which would ignite into an inferno when hit by enemy munitions. Early in the Korean War, US anti-tank rocket munitions would bounce off of Soviet-made T-34 Tanks. In Viet Nam, US and Army of the Republic of Viet Nam infantry would ride on top of M113 personnel carriers, outside of the vehicle and exposed to small arms fire, for fear that exploding mines would turn the inside of the carriers into death traps, thus rendering the inside of the carrier useless for protection, its primary purpose. How does this happen?

Realistically, designers can never be sure systems will perform as expected without extensive testing, including live fire testing, followed by prolonged operational use, including combat. Further, the laws of physics apply and it is almost impossible and unrealistic to optimize engineering of combat system design for every threat. Designs have to be optimized for the "most likely" expected threats. The rest of the threats must be addressed through doctrine, training and tactics. Moreover, it is impossible to predict all outcomes of combat engagement due to the synergistic effects of engagement variables based on any one engagement condition set, including crew factors, daylight, weather, range, weapon system cant and unlimited other factors. However, survivability and lethality risk can be improved through design, test, production, doctrine, tactics and training for deployment.

The desire to reduce survivability risk and increase lethality is how live fire test requirements came to be. We do gain first order insights from the results of live fire tests. Theoretically, live fire test and evaluation is a fundamentally sound concept. But are the current process results adequate for the expenditure level, in terms of manpower, time, facilities, equipment and dollars? Is live fire test and evaluation currently a good investment? Can live fire test and evaluation accomplish the stated objectives of ensuring that battle damage tolerance and damage control of our crew-carrying combat systems to actual threat weapons is known and acceptable and that the lethality of our conventional weapons (non-nuclear, biological, or chemical) against actual threat systems is known and acceptable?⁹

A parallel business process to Live Fire Test and Evaluation is practiced in Civilian Industry. For example, automobiles are crash tested under the supervision of the National Highway Traffic Safety Administration to determine crash worthiness and passenger survivability.¹⁰ The major difference is that automobiles are produced at much greater volume and much lower costs than the average Department of Defense weapon systems covered by Live Fire Test and Evaluation requirements. The average automobile costs in the twenty to forty thousand dollar range per automobile and defense systems covered by

⁹ Defense Systems Management College Fact Sheet 6.3, "*Live Fire Test and Evaluation (LFT&E)*", April 1995, pp. 6.3-1 to 6.3-2.

¹⁰ James F. O'Bryon, undated, slide 000132 and 000102.

the live fire test and evaluation process usually cost in the millions of dollars per copy.

Therefore, destructive testing by crashing civilian automobiles pays a much higher return on the investment for destructive testing than it can on expensive Department of Defense systems. The return on investment advantage of the automobile industry is intensified when considering the widespread and constant usage of automobiles by billions of people around the world. In short, the comparison between the two is specious at best. The fact that the Return on Investment for live fire test can't rival that of the automobile industry is still no reason not to have live fire testing of military systems though, if lives can be saved in combat and training - presuming the end state of the testing provides us with what, and enough of, what we need to know to make a difference and provide an overmatch of operational advantages relative to future adversaries.

The worthy objectives of live fire test and evaluation are:

- To enable Defense Department decision makers to make informed defense system acquisition decisions at the appropriate time in the system life cycle.
- To gain potential insights in to design flaws to provide opportunity for corrective action prior to full rate production (albeit late in the process).

- To understand system survivability and lethality against expected threats, and emphasize individual soldiers, sailors, airmen, marines and crews of each.

In short the purpose is to save lives in combat.¹¹ I submit the short purpose in the previous sentence mitigates the need for any specific return on investment. Still, we can conduct the process much better than we currently do.

Live fire test and evaluation is codified in law under Title X United States Code, Chapter 139, Sections 2362, 2366 and 2399.¹² Since Fiscal Year 1986, when initially placed into law in the Fiscal Year 1986 Defense Authorization Act, the coverage of systems has grown to cover more and more defense systems. Coverage has expanded from Tracked and Wheeled Vehicles in Fiscal Year 1986 to All major combat systems (Acquisition Category I or II) in Fiscal Year 1987, to the US Air Force C-17 Air Transport in Fiscal Year 1993, to Theater Missile Defense in Fiscal Year 1994. Coverage today stands at eighty systems in all services¹³ The Department of Defense established policy guidance to implement the law in Department of Defense Directives 5000.1 and 5000.2-M, Department of Defense Regulation 5000.2-R, and Department of Defense Instruction 5000.2.¹⁴

¹¹ Ibid., slide 000263.

¹² Defense Systems Management College Fact Sheet 6.3, p. 6.3-1.

¹³ James F. O'Bryon, slides 000030 and 000044a.

¹⁴ Defense Systems Management College Fact Sheet 6.3, p.6.3-1 and <http://www.dote.osd.mil/lfte/BBOOK.htm>

Along with the growth in coverage in Fiscal Year 1989, the Defense Authorization Act authorized the Secretary of Defense to Reprogram 0.3% of system procurement funds to fund Live Fire Test and Evaluation.¹⁵ In Fiscal Year 1994, the Federal Acquisition Streamlining Act transferred all Live Fire Test to the responsibility of the Department of Defense away from the services.¹⁶

All of this legislation was enacted and had the cumulative effect of significantly increasing the allocation of resources to live fire test and evaluation activities, at the very time that system procurement funds were plummeting to around thirty billion dollars per year for the entire DOD, a reduction in excess of 52% from 1989 levels.¹⁷ GEN. Shalikashvili, in his last Chairman's Program Assessment as Chairman of the Joint Chiefs of Staff, indicated that to maintain adequate readiness, the level of procurement needed to be at least at sixty billion dollars per year.¹⁸

We are still not at the recommended procurement level today at about forty eight billion per year in the current program. It is unlikely, given competing demands in the federal budget, and even within the Department of Defense,

¹⁵ James F. O'Bryon, slide 000030.

¹⁶ Ibid., slides 000005 and 000030.

¹⁷ "America's Army.....Into the 21st Century", Army Program Analysis and Evaluation Directorate, p.6. and the March 24, 1999 Statement on Modernization of the US Army by General Dennis J. Reimer, Chief of Staff, Army, before the Subcommittee on Airland Forces, Committee of the Armed Services, United States Senate, First Session, 106th Congress, p. 4.

that the Department of Defense will reach the sixty billion dollar per year level for procurement for years to come, if ever. Therefore, it is most interesting that live fire test and evaluation has been a growth process in an era of steeply diminishing Research Development Test & Evaluation and Procurement dollars, thereby consuming an ever greater share of an ever diminishing resource base!

Thus, not only was the timing of the Live Fire Test legislation financially inopportune, the effectiveness of the legislation is called into question since the Department is developing very few new weapons (and under different acquisition processes defined by the Performance Based Business Environment) and because the Department can not buy enough to sustain operational readiness of current systems at any rate.

This is not a unsolvable problem under current live fire test and evaluation paradigms though, as it could be fixed with additional funding, given a turn around in the resourcing climate. Recent developments in the Washington DC environment indicate that the resourcing climate may be improving, even if incrementally. The question is, will the 0.3% of procurement funds be effectively used and accomplish the worthy intent of the Live Fire Test and Evaluation program?

¹⁸ 1997 Chairman's Program Assessment.

At \$60 billion of procurement, live fire test and evaluation funds should be about \$1.8 billion at the 0.3% rate if the Secretary of Defense applies the 0.3% reprogramming to the entire Department of Defense procurement allocation. If the Secretary allows reprogramming of only the procurement funds for the covered eighty systems, then the available funds for live fire test are much less.

Even with the most optimistic funding projections, since most of the covered eighty systems cost in the millions of dollars, how much destructive testing of full-up systems can be accomplished at approximately \$22.5 million per covered system? Obviously not much, unless accomplished at the component level or by some means other than destroying full up low rate initial production systems, which is when the first full up systems are to be destroyed, and therefore the maximum amount of live fire test and evaluation activity is to be expected. As of October, live fire test and evaluation under the statutory and policy guidance had been completed on twenty five of eighty systems.¹⁹

Upon further analysis, we find that live fire test also includes Joint Live Fire Test and Evaluation, after the production decision and during upgrade activity later in the system life cycle²⁰ The difference in funding above the 0.3% of procurement funds is to be paid from service research, development, test

¹⁹ James F. O'Bryon, slide 000044a.

²⁰ Ibid., slide 000093.

and evaluation or procurement accounts, which are already woefully inadequate.

Furthermore, live fire test and evaluation, by the community's own definition, is a process, not an event.²¹ Activity is supposed to increase over time during operational testing to sequentially cover individual components, then multiple components, followed by subsystems, prototypes and full up systems in sequence.²² This presumably would be accomplished on the theoretically programmed \$22.5 million for each of the eighty systems. This funding level and requirement presents a considerable management challenge indeed.

What we have then at the end of this analysis is a process where there is a total strategy versus resources mismatch with resources being completely inadequate to accomplish the stated objectives. Worse yet, there are no prospects of the stated objectives ever being adequately resourced. Someone needs to tell the emperor he has no clothes.

Live Fire Test and Evaluation focuses on determining the acceptability of system vulnerability and crew safety, or the probability of being killed if hit, also known as Pk/h. System survivability (Ps) is defined by the relationship $1 - (P_a/e)$ times the

²¹ Ibid., slides 000093, 000047, 000017, 000050.

probability of being hit given an attack (also known as Ph/a) times Pk/h, or restated, $P_s = 1 - (P_a/e \times P_h/a) \times P_k/h$.²³ This is a complex outcome based on the relationship of type and power of munitions in the attack, shot lines, points of impact, and terminal munitions effects, and is very difficult to predict without destructive testing. The outcome is essentially valid only for a single selected set of test criteria since changing munitions, shotline, point of impact, or "fog of war" would alter the synergistic terminal effects of the engagement. The same set of conditions apply to lethality testing of munitions, only in reverse.

Moreover, live fire test focuses only Pk/h which is a dependent variable of Pa/e and Ph/a. So clearly Pk/h can be mitigated by a wide variety of factors such as, tactics, doctrine, weather, daylight and many more factors other than system design. This gives the live fire test and evaluation process an exceedingly difficult set of factors under which to prove (or disprove) system survivability or lethality.

III. Acquisition Reform

Enter Acquisition Reform and overlay the effects of Acquisition Reform upon the requirements and developments of the live fire test and evaluation legislation and program of the Department of Defense. With the ascendancy of the Clinton administration in 1992, everything in the defense acquisition process was soon to change. One of the first acts of the administration was to

²² Ibid., slides 000017 and 000050.

conduct the National Performance Review which led to the Reinvention of Government Initiative. In the Defense Department this manifested itself in the Revolution in Business Affairs and Acquisition Reform, discussed earlier. Acquisition Reform touches every single aspect of the Defense acquisition process including: concept development, engineering, developmental and operational testing, contracting, property administration, quality assurance, packaging, transportation, disposal and others not mentioned here. In most regards it has manifested itself by slashed budgets and large reductions in acquisition personnel to be replaced by information age capabilities, such as digitizing business processes and simulations. Has acquisition reform touched the Live Fire Test and Evaluation Program of the Department of Defense? It would appear that it has not in any substantive way.

The overriding change in acquisition reform has been fostered by the advent of the Performance Based Business Environment. The Performance Based Business Environment creates a vision of a quality, business - like environment that simplifies and takes advantage of the basic acquisition and sustainment tools to enhance the products we provide to the warfighter.²⁴ It is characterized by the following:

- Dual use products and processes.

²³ Ibid., slide 000084.

²⁴ LTC Dennis Drayer, p. 58.

- World class processes.
- Commercial state of the art technologies.
- Integration of commercial and military development.

The end state objective is to provide better, faster, less expensive systems and smoother operations.²⁵ Philosophically, the Performance Based Business Environment shifts the defense acquisition process, including test and evaluation, from a process of Risk Avoidance to Risk Management.²⁶ The objectives are:

- Convey product definition and key process expectations (specifications) to industry in terms of performance.
- Promote life cycle systems engineering and management practices (including integrated product development process and support).
- Increase emphasis on past performance.
- Shift from a cost - based (plus profit) to a price based procurement system (including profit).
- Motivate process efficiency and effectiveness up and down the entire supplier base.
- Encourage life cycle risk management instead of risk avoidance.
- Simplify acquisition and support operating methods.²⁷

²⁵ Ibid., p.58.

²⁶ Ibid., p.60.

²⁷ Ibid., p.60.

Nowhere was test and evaluation exempted in this philosophical change. The fundamental shift in the Performance Based Business Environment was the advent of performance specifications in lieu of military specifications and standards. What has this done to the defense acquisition community? First, it has shifted responsibility for configuration control and technical data package control from the government to industry. Instead of control, product managers and requiring agencies have only insight and influence. No longer can we tell the contractors how to do the thing, we can only tell them the thing we want to do.

This new philosophy has been in effect in the Army since 1992. If the contractor feels he has a better, less expensive, faster product, material or process then it may be adopted. The program manager is only to be informed and there is little the program manager can do unless the changes violate the fundamental performance requirements e.g. size, weight, speed, altitude, cost or price and others. In former times making such changes could even be illegal and prosecutable under fraud legislation for product and process material substitutions.

Acquisition Reform and the use of performance specifications has also collided with the dearth of sustainment, research and procurement funding to create spin - off concepts and programs such as modernization through

spares and technology insertion or appliqué. In modernization through spares, a combat system will be modernized when major components or sub-components are replaced. This is accomplished by replacing an older engine with a new more modernized engine in a tank or helicopter, for example. Other types of modernization can occur to fire control systems, protection or survivability systems, communications systems, and any other subsystem below the top level combat system.

In technology insertion or appliqué, a new lower tier system that may not have been a part of the original top level system is inserted into the top level combat system or overlaid on the top level combat system, provided there is an adequate space, weight or size allowance. An example of this would be the Army's ongoing Horizontal Technology Integration effort to digitize Army combat forces. The intent of both of these concepts is to make the current existing top level system more capable in an era when there is inadequate funding in the Defense Budget to develop completely new systems from a paper concept. Both approaches are very pragmatic and sound given the current acquisition resourcing environment.

But what is the synergistic impact of acquisition reform efforts on Combat system configuration, configuration control, and stability?. In short, the impact is phenomenal. The US Air Force has recognized for years, even before Acquisition Reform, that in aircraft production lines, combat system

improvements were being applied, often to almost every new aircraft on the production line. This situation led to a case where almost no two aircraft were the same. Acquisition Reform has accelerated this process, and looks to accelerate the effect even more in the future, as many new defense contractors are coming on line with performance specifications and are operating in the performance based business environment. The extended life of combat systems in the current resource constrained environment will only amplify the impacts of Acquisition Reform on combat system configuration due to the Performance Based Business Environment, Technology Insertion, Modernization Through Spares and other such efforts.

This rapid application and acceleration of the Performance Based Business Environment impact every aspect of Defense acquisition: contracting, program management, quality assurance, production, acquisition logistics, developmental and operational test. It also impacts live fire test & evaluation in a tremendous way.

IV. Live Fire Test & Evaluation and Acquisition Reform.

As previously discussed in Section II of this paper, the science and mechanics of live fire test and evaluation is largely one of terminal effects of combat engagement and impact dynamics, which is very complex. Acquisition Reform has made them more complex than before. Results of the

engagement and impact dynamics is highly synergistic and depends on multi-varibale analysis and is difficult to predict. It is known however, that interactions between sub-components of the system design is what yield the survivability or lethality results. Why then, do we place so much reliance and resource so heavily on the result of one specific solution set of variables when that particular solution set has a low probability, approaching zero, of ever being repeated again? Not only is the variable solution set unlikely to be repeated, it is highly difficult to replicate, which is a key requirement of science. However, since testing, though not a statistical exercise, is based in probabilities and distributions to certain scenarios, i.e. 60% of all engagements will be frontal shots, at 4 to 6 km range, traveling at 15 mph..., live fire testing should be able to baseline a few scenarios with a level of confidence and then iterate using simulation to examine the "what ifs" and the outliers.

The replication difficulty comes from two sources that I will call environmental factors and hardware factors. First, I will refer to the environmental factors as the munitions used, the range, the weather, the shot line, the point of impact, crew actions and many other such variables. Combat and maneuver are highly dynamic. The same set of environmental criteria will likely never be replicated on the battlefield; even if what we did on the range could be replicated with a high degree of consistency, the range would be irrelevant to actual combat.

Second, acquisition reform has injected a whole new set of variables, external to all of the environmental factors, which I will refer to as hardware factors. That is to say that no two future combat systems are likely to have exactly the same configuration and Technical Data Package. Even though this is true, all of the substitutions still have to meet performance requirements e.g. form, fit and function. The rate of configuration change between systems is the key figure of merit that needs to be investigated. Because no two systems are likely to have the same configuration under Acquisition Reform, the effect is to change the internal component impact dynamics between every "similar" system. In short, no two tanks are likely to be configured the same in the future, so where is the "value added" for a single live fire test and evaluation event, costing millions of dollars, on one specific system that is different than one that rolled off of the production line after it? It is my contention that the "value added" due to environmental and hardware factors is, while not insignificant, severely limited. To continue the current live fire test and evaluation process into the future without significant improvements is to ignore reality and fail to obtain maximum benefit from our scarce resourcing.

Proponents of the current live fire test and evaluation process would respond to my contention that statistical significance for a Live Fire Test and Evaluation Event is unnecessary. The live fire test and evaluation proponents contend that we learn much from a single shot.²⁸ I agree with this statement

²⁸ James F. O'Bryon, slide 000290.

but it ignores the issue. "Much" is a very subjective term. Usually, in munitions testing of Precision Guided Munitions, at least 50 expensive shots are required to gain only a statistically insignificant 70% to 80% confidence level.²⁹ The issue is are we obtaining the most "value added" from that single shot (or 50), and the expenditure that goes with it? I contend that we are not and process reengineering is in order. Well then, if we can't hope to hold system configuration stable and our live fire test & evaluation events only tell us about a specific configuration and a specific fire solution set, what are we to do? Fortunately, it is my hypothesis that we have the intellectual ability and the technology at hand to address this issue and I will discuss this in the following paragraphs.

V. Proposed Changes to the Live Fire Test and Evaluation Process.

First of all, abolition of the live fire test and evaluation process is not recommended. Further, a reduction of live fire test and evaluation funding is not necessarily in order, although new processes could eventually lead to reductions in live fire test and evaluation funding requirements at some point. This paper's recommendations will take the form of business process re-engineering and management changes. There are no apparent reasons why the recommended changes can't take place within the context of the existing

²⁹ From an interview with Lieutenant Colonel Jody A. Maxwell, USA, former Product Manager of the Apache Longbow Hellfire Missile and recipient of the 1998 Daedalian Award for his performance of duty.

legislation, policy and funding. Therefore there is no apparent requirement to request any legislative changes.

First, the most sensitive changes usually involve resource reductions to facilities, manpower, or dollars. Without examining the long term impact of this paper's recommendations, no reductions in any resources dedicated to live fire test and evaluation process are recommended at this time. Indeed the Director of Operational Test and Evaluation proposes that it is time to increase investments in Test and Evaluation in general.³⁰ The fundamental issue before us is, "What is the best way, in the current Performance Based Business Environment and Acquisition Reform environment, to ensure combat system survivability and munitions lethality?". Restated, "What is the best way to obtain a high degree of system confidence in operational suitability and effectiveness?" It would appear that funding based on a rate of 0.3% of procurement resources per year of a proposed \$60 billion procurement budget, or about \$18 million, is not exorbitant and is furthermore a prudent investment in the lives of our service people. How do we use this \$18 million to obtain what benefit is the key issue.

Second, live fire test and evaluation program responsibility changes are not recommended. The independence of the live fire test and evaluation community, as it currently stands, is a prudent management structure. It is a

³⁰ "Program Manager Interviews Philip Coyle", Program Manager Magazine, May-June 1996, pp. 2-8.

fundamentally sound approach for the live fire test and evaluation community to remain the conscience of the acquisition system, separate from the materiel development or requirements development communities. Even though the integrity of Defense Program Managers is correctly presumed, pressures are strong on Program Managers to get their systems into production from the service users. Often, any new system can be better than what is currently fielded. Strong pressure can be brought to bear on Program Managers such that there exists a legitimate viewpoint, by the service - if not the program manager, that it is more desirable to field a flawed system and fix it later, than to get it right first. This inherent conflict of interests can't be allowed to override the well being of our volunteer warriors.

This paper's first recommendation is that the live fire test and evaluation community must effect a culture shift must get on board with Acquisition Reform now. In the live fire community there appears to be an attitude and culture of, "This does not apply to us and we are exempt." Nothing could be further from the truth. It applies to the live fire community whether they want it to or not, even if they do engage in wishful thinking. This attitude is manifested by comments such as the following:

"We have no evidence to show us that you can substitute modeling and simulation in the live fire world for live fire tests."³¹

³¹ John Burt, Defense News, August 1-7, 1994, p. 22.

"It is a waste of time and money to pursue vulnerability modeling any further. Experience over the past twenty years has shown that we have been unable to validate these models. Why has this been the case? The events to occur inside a combat configured vehicle that has been struck by a weapon are complex, non-linear and far from equilibrium. These are the characteristics of chaotic systems. As a result of studies in this new non-linear science, we know that we can only describe complex, non-linear events after the fact, not before the fact. More computing power and more data does not allow us to more precisely describe what has already occurred. So the prospects of ever developing and validating useful vulnerability models seems remote."³²

"Simulation Based Acquisition does not apply to Live Fire Test & Evaluation"³³

The live fire test and evaluation community clearly needs to get with the program. To think that the rapidly advancing mathematical fields of Chaos Theory and Non-Linear Analysis are not capable of ever describing impact dynamics is merely wishful thinking at best and arrogant at worst. In fact, the same arguments the live fire test community makes against simulation can be turned against them given the highly variable nature of the live shot business!

Mathematical modeling, especially when used in concert with super-computing and parallel computer processing capabilities is becoming ever more powerful. Selected models may be inadequate today, but they should be vigorously pursued, with a significant portion of the live fire test and evaluation resourcing base allocated to developing the mathematics, the models, the interfaces with live fire data, and verification and validation. This is an

³² Colonel James Burton, May 21, 1995 (and subject of Home Box Office Special Motion Picture, "*Pentagon Wars*") as quoted by James F. O'Bryon, slide 000299.

³³ James F. O'Bryon as quoted by Dr. Jerry Davis at the 1998 Simulation Based Acquisition Conference.

especially prudent in view of Moore's Law which states that computing power doubles about every eighteen months.

The developmental test community and the operational test community have recognized this fact of life. The Army has done significant development of the "Virtual Proving Ground" at the US Army Test and Evaluation Command with locations around the world. The operational test community is putting significant resources into system on system and force on force models. The Joint Advanced Distributed Simulation Joint Test Force, located in Albuquerque, NM, has conducted three significant tests integrating simulation using data baselined from actual shot data. The most successful and promising of the three tests was simulating the AMRAAM missile Precision Guided Munition.

Simulation is not cheap. It takes resources to develop models, test set-ups, and interfaces with real events. The test simulation architecture for the AMRAAM test cost \$600,000. However, each AMRAAM Missile costs \$250,000 not counting the aircraft and test infrastructure support.³⁴ This simulation provided the capability to iterate any desired number of AMRAAM shots within the system architecture, once established. Further, the simulations were based on live shot data. While it is true that there were some constraints and anomalies, the problems seem to be readily solvable with a modicum of effort.

³⁴ Lieutenant Colonel Pat Cannon and Mr. Eric Keck, "*Advanced Distributed Simulation - A Toll for the Tester's Toolbox*", Joint Advanced Distributed Simulation Joint Test Force, Albuquerque, NM, pp. 52-58, 73-77, 83-87, 93, 97-114.

Moreover, it does not take too many live AMRAAM shots (three to be exact) to exceed the cost of the test simulation architecture, which provides as many shots as desired and affordable. The live data -simulation linked scenario was certainly more effective and less expensive than a pure live fire scenario would have been.

There is hope that the cultural shift can occur. A leader in the live fire community, Mr. Jim O'Bryon, The Deputy Director for Live Fire Test and Evaluation at the Office of the Secretary of Defense states in his briefings that, "Testing and modeling and simulation are intertwined, and when they are not, neither is effective."³⁵

He further goes on to offer many good reasons for modeling while mitigating that enthusiasm by offering cogent reasons that live fire tests are essential.³⁶

Couple the mathematical progress with increasing computing power and it will not be long until simulations can describe events with a significant degree of accuracy. Therefore, the second recommendation is a resource allocation recommendation to dedicate an adequate portion of the live fire 0.3% set aside of the procurement budget to be invested in live fire test and evaluation system architecture improvements, model developments and

³⁵ James F. O'Bryon, slide 000033.

³⁶ Ibid., slide 000300.

linkages of impact dynamic simulations to actual test event data. This will pay off in the future and must be done to account for the speed with internal configuration of systems is changing under acquisition reform. Otherwise the secondary effects data from live tests events (debris, ricochet, spalling, etc.) are only valid for the particular configuration tested and the engagement variable set tested and therefore of limited value at exorbitant cost. The same is true for synergistic cascading effects. To make the events relevant we would have to build two of every configuration change and destroy one, a clearly unaffordable approach, and would still be valid only for a specific set of engagement criteria.

The third recommendation is that these simulation models must be linked to actual live fire test data. This live fire data would provide a baseline and would allow simulation excursions to account for changing configurations. When the time comes for another live fire event, then the simulation can be re-baselined or validated. Then the question becomes, how will we know when it is time for another live fire event to obtain new baseline data? Restated, when has the configuration of the system changed so significantly that it is rendering the results of the simulations suspect or invalid? The answer to this question is the key objective of the developed simulation models and iterations. The effective reform of the live fire test and evaluation process would thus require both a reduced number of live shots and a vastly increased number of effective simulation iterations, but would still require both to provide value and relevancy.

Improving the models and linking them to computing power is "the long pole in the tent" so to speak. Linkage requires time, research and development resourcing and should be started immediately. The fourth recommendation is a management change and can be implemented with little or no resourcing. Risk management techniques, in combination with the linked simulation and actual live fire event data, should be employed to determine the milestones for live fire events. We know that as system configuration changes from that which was tested by live fire event, the relevance of a simulation would decrease over time. However, we need not, and indeed cannot afford to, test every configuration change. Risk analysis must be done to determine when a new live fire event is required when the configuration of the system has changed so significantly that the results of the old live fire event - simulation linkage are largely invalid. Then it is time to schedule and resource a new live fire event.

The principles of Risk Management are well known in the Department of Defense. They have been taught for years at the Defense Systems Management College and have taken on new significance in the environment of Acquisition Reform and resource constraints. One of the foundations is Cost as an Independent Variable. This concept essentially states that there are risks to be taken and risks to be avoided by use of appropriate risk

management and contingency plans.³⁷ The establishment of a Risk Management Working Group that included representatives of the Program Office, Contractor, User, and Live Fire Test and Evaluation communities is also called for as part of the accepted Integrated Product and Process Development concept³⁸ In short , the Live Fire Test and Evaluation community can no longer be a totally detached gate keeper. While remaining independent of the services and programs, they must nevertheless be part of the planning and problem solving process. This Risk Management program should have all of the following components:

- Risk Planning
- Risk Assessment (including identification and analysis)
- Risk Handling
- Risk Monitoring

Each component should be documented so that assumption of risk is known and agreed to by the proper authority level.³⁹

³⁷ Mark D. Schaeffer, "Risk Management in the Department of Defense: Identifying Risks to be Taken and Risks to be Avoided", Program Manager Magazine, March-April 1998, p.48.

³⁸ Ibid., pp. 49-50.

³⁹ Ibid., p.52.

VI. Summary.

The Revolution in Business Affairs is now six to eight years old. The only certainty is that everything in defense business is changing and at an ever accelerating pace. Acquisition Reform and the Performance Based Defense Business environment have changed almost everything about the way we develop and procure our defense weapons systems. The advent of and the emerging maturity of the simulation based acquisition techniques promise more changes in the future. It is the assessment of this paper that only one aspect of defense acquisition has stood firm against this onslaught of change and reform, with little to no change to product or process, and that would be the live fire test and evaluation process and community. This can not continue if this key community is to retain affordability and relevancy to the defense acquisition process, which it must!

The tools to provide a better live fire test and evaluation process and product are available and for the most part in place. Simulation technology is rapidly maturing. Computing power is leaping ahead every eighteen months. Risk management techniques are well developed and well known in the Department of Defense. The live fire test and evaluation community has their own funding and they have authority provided to them by law and by policy. Why then is there no evident action to improve the live fire test and evaluation business process and product as is happening in every other aspect defense

acquisition and test and evaluation, like the advent of the virtual proving ground?⁴⁰ There does not appear to be an answer to this question short of saying it is nice to be in a comfort zone. The live fire test and evaluation community must establish a vision and a plan, including resourcing, for relevancy in the future, or they will become irrelevant. My hope is that this changes in the very near term. Perhaps this paper can be a catalyst. The live fire test and evaluation program is too important to the well being of our warriors. As important as the process is, it can not continue spending millions for dubious "value added" output. It is my sincere hope that the change has already begun and that I simply could not find it and that the community leaders are re-engineering this critical aspect of defense acquisition as this paper is being written.

⁴⁰ Virtual Proving Ground, <http://vpg.apg.army.mil>

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