NPS-AM-09-041

ACQUISITION RESEARCH SPONSORED REPORT SERIES

The Stryker Mobile Gun System:
A Case Study on Managing Complexity

08 June 2009

by

MAJ Christian C. Ayers, USA

Advisors: John Dillard, and

Dr. Keith Snider

Graduate School of Business & Public Policy

Naval Postgraduate School

Approved for public release, distribution is unlimited.

Prepared for: Naval Postgraduate School, Monterey, California 93943

The research presented in this report was supported by the Acquisition Chair of the Graduate School of Business & Public Policy at the Naval Postgraduate School.

To request Defense Acquisition Research or to become a research sponsor, please contact:

NPS Acquisition Research Program
Attn: James B. Greene, RADM, USN, (Ret)
Acquisition Chair
Graduate School of Business and Public Policy
Naval Postgraduate School
555 Dyer Road, Room 332
Monterey, CA 93943-5103
Tel: (831) 656-2092
Fax: (831) 656-2253
e-mail: jbgreene@nps.edu

Copies of the Acquisition Sponsored Research Reports may be printed from our website www.acquisitionresearch.org

Abstract

This case study analyzes how the Stryker Mobile Gun System (MGS) program managed complexity. The MGS is one of the ten variants of the Stryker series of vehicles that equip the Army's Stryker Brigade Combat Teams. These brigades were created by the Army Chief of Staff (from 1999–2003), General Eric Shinseki, to provide the Army with a highly deployable medium-force capability. Initially intended as a variant that required limited development, the MGS experienced a number of significant challenges during systems development.

This case study uses one of the program's primary issues, reliability shortfalls with the ammunition handling system, to describe how the program self-organized to manage complexity. The case study identifies the elements of complexity that existed in the Defense Acquisition System (DAS), and how they interacted to create a challenging situation for the MGS program.

After a crisis period from 2004–2005, the MGS program changed its acquisition approach through the revitalization of systems engineering and risk management. This case study examines the self-organizing methods that the MGS program used to improve system performance, and it concludes with a description of how acquisition programs can better align their acquisition strategy to achieve programmatic resilience.

Keywords: Stryker Brigade Combat Team, Interim Force, Mobile Gun System, Complexity, Uncertainty, Systems Engineering, Reliability, Risk Management, Acquisition Strategy

THIS PAGE INTENTIONALLY LEFT BLANK

Acknowledgements

This case study benefitted both directly and indirectly from the generosity of many people. I can always count on my wife, Jessica, who provided the love and patience I needed to make this experience enjoyable. My two children, Samuel and Madelyn, inspired me to work as efficiently as possible so I could have time to spend with them.

I want to express my sincere appreciation to my two advisers, Mr. John Dillard (COL, ret.) and Dr. Keith Snider (LTC, ret.). I am indebted to them for keeping me on track and encouraging me with excellent feedback. I am indebted to the Project Management Office, Stryker Brigade Combat Team, particularly to COL Robert Schumitz, Mr. Joseph Godell, Mr. Steve Dawson, and Mr. Gary Gerlach, for their tremendous assistance and insight. I would also like to thank Ms. Kimberly McCormick and Mr. Josh King from the General Dynamics Land Systems MGS program office for their perspectives and technical assistance. This thesis also benefitted from those who granted interviews, advice, and assistance throughout the process to include LTG (ret.) Joseph Yakovac, Rear Admiral (ret.) Donald Eaton, Mr. Mike Viggato (Deputy PEO GCS), Dr. Larry Jones, Dr. Keebom Kang, Dr. Rene Rendon (LTC, Ret.), LTC Eric Webb, LTC Shane Fullmer, and Ms. N. Jenny Chang.

THIS PAGE INTENTIONALLY LEFT BLANK

NPS-AM-09-041

ACQUISITION RESEARCH SPONSORED REPORT SERIES

The Stryker Mobile Gun System: A Case Study on Managing Complexity

08 June 2009

by

MAJ Christian C. Ayers, USA

Advisors: John Dillard, and

Dr. Keith Snider

Graduate School of Business & Public Policy

Naval Postgraduate School

THIS PAGE INTENTIONALLY LEFT BLANK

Table of Contents

I. Introduction

A. Diyala Province, 2008

The platoon sergeant from Alpha Company, 1st Battalion, 38th Infantry Regiment had thoroughly prepared his Mobile Gun System (MGS) platoon for their reconnaissance mission in the Diyala Province, an area northeast of Baghdad that was a hotbed of insurgent activity. With over 19 years in the Army, the platoon sergeant understood the process of preparing Soldiers for a mission (known as Troop Leading Procedures), and he was aware of the potential problems that could easily arise in such a complex environment. The Army trains its tactical leaders to integrate the Troop Leading Procedures as early as possible in the planning process and to maximize the use of time.

The platoon's mission from their higher headquarters was to "get eyes on" a small town in their sector by using the sophisticated array of day and night optics on the MGS (see Figure 1) (Pappalardo, 2008, March 11). To visualize the battlefield, the platoon sergeant used the limited amount of information that he had on the enemy and the three-dimensional terrain to build situational understanding for the platoon, but he knew that this picture was imperfect. While moving to their observation point, the platoon sergeant's MGS was struck by an improvised explosive device (IED) "that blew out eight tires and one antenna mount" (2008, March 11). Although the tremendous blast jarred the crew, they were able to execute one of their contingency plans and move the vehicle to a secure area 2600 meters away to execute their preplanned battle damage and repair procedures (2008, March 11).

During mission planning, the MGS platoon leadership identified hazards and developed controls to mitigate those risks in a process known as risk management (TRADOC, 2005, November 20, p. E-1). The effectiveness of the risk management process requires situational understanding and controls that the platoon's leadership adapts to the particular hazard and situation (2005, November 20, p. E-1).

Figure 1. M-1128 MGS
(GDLS, 2005c, slide 2)

Soon after they conducted the battle damage and assessment drill and brought the vehicle to an operational status, the platoon got back onto the road. Within minutes of getting the platoon back onto the road, a second IED struck the platoon sergeant's vehicle (Pappalardo, 2008, March 11). This time, the crew's gunner was able to identify "the triggerman on the roof of a building 820 feet away" and with no tires or communications equipment, the platoon sergeant's vehicle was able to "engage the spotter with 20 rounds [7.62mm machine gun], while on the move to eliminate the threat" (2008, March 11). Despite two IED strikes, the platoon maintained its resiliency in the face of uncertainty and completed its mission without the loss of life.

Risks are an inherent part of any mission, and the platoon was able to complete its mission because its leaders properly anticipated these risks and developed controls to reduce the severity of the consequences. During the mission, the platoon sergeant demonstrated the integration of risk management and knowledge management into his Troop Leading Procedures. The synchronization of these processes was critical to his platoon's ability to accomplish the mission without the loss of life. Yet, the synchronization of these processes required the application of the platoon sergeant's will and an understanding of battle command.

B. Systems Acquisition: A Complex and Uncertain Mission

Just as the tactical leader in the Diyala vignette had to synchronize processes, the program manager must synchronize his or her program in time and space to achieve effective results while navigating a complex and uncertain defense acquisition system. Just as the MGS platoon sergeant synchronized risk management and knowledge management into his Troop Leading Procedures, the program manager must do the same to exercise resilient and agile program management. The program manager must also work with imperfect information while making decisions on development, testing, production, and logistical support that will affect the program over its entire lifecycle.

The Mobile Gun System, one of the ten variants of the Stryker series of vehicles, conducted its first operational deployment to Iraq as part of the 4th Stryker Brigade Combat Team, 2nd Infantry Division in 2007. During its first operational deployment to Iraq, the MGS received positive feedback. In the words of the platoon sergeant from the Diyala vignette, "it is the most lethal ground vehicle for an urban environment in Iraq today" (Pappalardo, 2008, March 11). However, the vehicle experienced a challenging development process.

C. Research Question and Methodology

1. Research Question

This case study had one primary research question: How did the Mobile Gun System Program Management Office (MGS PMO) manage complexity? From the primary research question, the researcher developed several supporting research questions:

- What was a significant developmental problem experienced by MGS that required the MGS program to revise its approach?
- What was the root cause of the developmental problem, and what corrective actions did the program management office take to improve the system?
- What is complexity theory, and how does it apply to products and systems?
- How did the MGS PMO self-organize to adapt to the complex environment, and what insights can the case study use to apply to other systems acquisition programs?

2. Methodology

This case study focused on the program's first six years of development from 2000–2006, granting the case study a historical perspective. The case study used a specific issue encountered during the MGS development as a means to study how complexity affected one particular systems acquisition program. The case study then identified the methods, techniques, and approaches that the MGS Product Management Office (MGS PMO) and the prime contractor, General Dynamics Land Systems (GDLS), used to manage the complexity.

The first step in the research process was to obtain information for the case study from several different sources. The researcher focused on documents and information available through open sources such as defense publications and newspapers. The researcher then transitioned to a literature review on complexity theory.

The next step in the research process was to interview members of the Project Management Office for the Stryker Brigade Combat Team (PM SBCT). Since the development of the MGS is still in progress, many of the program's key participants were available for interviews. These interviews played a critical role in providing information for the case study. As part of the research process, the author arranged interviews with current and former government and private-sector individuals who were involved with the development of the MGS both directly and indirectly.

According to Robert K. Yin, the author of *Case Study Research*, the researcher should approach a case study as an open-ended investigation (Yin, 2003, p. 90). Each interview served as a source of information, but the research had to corroborate all of the information gained from the interview to present a clear and concise case. When conducting the interviews, the author focused the questions on, "satisfying the needs of [the case study's] own line of inquiry while simultaneously putting forth friendly and non-threatening questions in open ended interviews" (2003, p. 90).

3. Limitations

The case study attempts to fill some of the gap between the literature on complexity in the defense acquisition environment and the literature on how program management offices manage complexity. The case study uses a recent Army acquisition program to provide relevant lessons learned for acquisition professionals.

The case study has two main limitations. First, it attempts to draw conclusions on how an acquisition program managed complexity by analyzing a segment in time, 2000-2006. The case study also focuses on one specific development issue: reliability growth. The main limitation of this approach is that it does not fully address everything that the MGS PMO conducted during this period.

Second, the author was able to interview a broad range of individuals from both the government and the private sector for the case study, but it is possible that bias existed within the interview content. To mitigate this, the author interviewed several individuals from multiple periods to increase the level of objectivity.

D. Organization of the Case Study

The case study specifically addresses one critical challenge of the MGS development, but in a wider sense, this is not the purpose of the case study. The discussion of the reliability shortfalls is merely a means of discussing how programs self-organize in the face of complexity. Therefore, it was necessary to start from a very broad perspective when addressing the Mobile Gun System program's management of complexity.

In Chapter I, the case study introduces the research question, the methodology, and the organization of the case study. The opening discussion on the Diyala vignette frames the case study's analysis.

Chapter II, "What is Complexity," introduces complexity theory, and it starts from a very broad perspective with a discussion of several different theories. As the chapter progresses, it focuses the discussion on complex programs. In addition to discussing complexity in programs, Chapter II also discusses the use of systems engineering, risk management, and strategic planning.

In Chapter III, "The Road to Stryker," the case study provides a context to the outer environment that led to the Interim Force, which was later renamed Stryker. Chapter III discusses the Stryker's champion, General Eric Shinseki, who articulated the vision for the Interim Force during the October 1999 Association of the United States Army convention. "The Road to Stryker" also discusses how the acquisition reforms of the 1990s affected both the Stryker program as well as its urgency.

Chapter IV, "The Development of MGS," provides a more focused discussion on the MGS. In this chapter, the case study describes the unique requirements of the MGS and the approach that the program manager took in developing the system. Chapter IV also provides a chronological history of the development through 2008 to familiarize the reader with the program.

Chapter V, "Managing Complexity," focuses on the reliability issues associated with the MGS ammunition handling system. The chapter then analyzes how the program self-organized during a crisis. The chapter closes with a discussion on the application of complexity theory to the MGS. During this discussion, the author develops several insights on the key aspects of the program's self-organization.

Chapter VI, "Conclusion and Lessons Learned," takes the insights from Chapter V and discusses program synchronization with a wider perspective. Chapter VI then closes with six lessons learned along with several recommendations for other systems acquisition programs.

THIS PAGE INTENTIONALLY LEFT BLANK

II. Complexity—A Literature Review

A. Introduction

To gain a greater appreciation for the concept of complexity in product development, this case study cast a broad net, starting with a review of several seminal perspectives on complexity. This literature review progressively scopes the subject of complexity from a broad discussion to one focused on products and systems. The purpose of this chapter is to describe the theoretical framework for the case study, with a focus on complexity.

The MGS program encountered complexity both internally and externally during its development. Before delving into the nuances of the MGS program's complex environment, it is important to understand the sources of complexity. Maier and Rechin (2000) provide a strong case for understanding the sources of complexity when studying technical problems:

> It is generally agreed that increasing complexity is at the heart of the most difficult problems facing today's systems architecting and engineering. When architects and builders are asked to explain cost overruns and schedule delays, by far the most common, and quite valid, explanation is that the system is much more complex than originally thought. The greater the complexity, the greater the difficulty. (p. 24)

It is not the intent of this literature review to provide an exhaustive review of all sources on complexity; rather, this chapter discusses how complexity relates to products and systems. This section provides several theoretical views on complexity, a description of complex products and systems, characteristics of management systems for complex systems, potential problems encountered with the management of complex systems, the use of the systems approach, risk management, and strategic planning in complex programs.

B. What is Complexity?

The term "complexity" frequently describes anything that consists of many interrelated parts or is difficult to explain in simple terms. One can easily find over thirty definitions of complexity from different sources, and this section will start by discussing three of these definitions. These perspectives are from Stuart A. Kauffman, Herbert A. Simon, and Peter M. Senge.

1. Self-organization

In *The Origins of Order*, Kauffman (1993) provides a view of complexity from a physical and biological standpoint. Within a complex network, he discusses three regimes of behavior that include ordered, complex, and chaotic (1993, p. 183). The complex regime is an area on the border between order and chaos. The dynamics of this complex regime are sensitive to the initial conditions and can easily change, based on the parameters. Once parameters are changed, Kauffman describes the small and large changes within the complex regime as "avalanches" that affect the entire system (1983, p. 174). He refers to systems that are able to adapt to the changes in parameters as "self-organizing," and this occurs through the accumulation of useful variations (Kauffman, 1993, p. 174). While Kauffman addresses the complex regime that bordered on chaos and order, Simon sees complexity in hierarchical terms.

In *The Sciences of the Artificial*, Herbert A. Simon (1981) refers to complexity as something that is "made up of a large number of parts that interact in a non-simple way" (1981, p. 195). Simon believed that complexity was hierarchical in nature and that each system within the hierarchy had its own unique sub-systems. He describes this as a "box within a box," with each complex system consisting of both an inner and outer environment (Simon, 1981, p. 148). The outer environment serves as the operating environment for the inner environment, and the outer environment is the inner environment's primary source of complexity. For its part, the inner environment is constantly adapting and insulating itself from the variations emerging from the outer environment; he refers to this concept as a "design problem" (Simon, 1981, p. 134). The inner environment's design quality also depends on the limited data available from the outer environment, and this leads to a high level of uncertainty and ambiguity.

In his article, "Rationality as Process and as Product of Thought," Simon stated that "in complex situations there is likely to be a considerable gap between the real environment of a decision and the environment as the actors perceive it" (1978, May, p. 8). When a decision-maker addresses uncertainty and gaps in perception, he or she can either "satisfice" or seek an optimal solution. Satisficing occurs when the search for a solution "terminates when the best offer exceeds an aspiration level that itself adjusts gradually to the value of the offers received so far" (1978, p. 10). Optimizing occurs when the "correct point of termination is found by equating the marginal cost of search with the marginal improvement in the set of alternatives" (1978, p. 10). In many situations, the uncertainty of the situation causes the decision-maker to arrive at intuitive decisions that are good enough. Two methods for satisficing are using "feedback to correct for unexpected or incorrectly predicted events" and feed-forward, which is "based on predictions of the future, in combination with feedback, to correct the errors of the past" (Simon, 1981, p. 44). Feed-forward requires some awareness of the predicted consequences of decisions.

Feed-forward is challenging for organizations because people have difficulty maintaining awareness over such a large number of potentially relevant considerations (Simon, 1978, p. 8). Over time, these organizations learn "in the form of reaction to perceived consequences," and this learning is the dominant way that rationality develops in an environment of uncertainty (1978, p. 8). The large number of potential considerations makes a situation or problem complex. The interrelated nature of these problems makes rational decision-making more difficult because of the second- and third-order consequences.

2. Dynamic versus Detail Complexity

Senge (2007), the author of *The Fifth Discipline*, differentiates problems that exhibit detail complexity and dynamic complexity. Detail complexity consists of a brief snapshot in time of a relatively static system in which there are many different variables to explain cause and effect (2007, p. 71). The preponderance of analytical and forecasting tools that are currently used address detail complexity. Problem-solvers who are accustomed to solving problems involving detail complexity frame the problem as a closed event in terms of time and space. However, the analytical and forecasting tools that use detail complexity do not provide a clear cause and effect with dynamic complexity because cause and effect are "subtle and the consequences of actions occur over time" (2007, p. 71). Senge describes several situations in which dynamic complexity may exist, including:

> When the same action has dramatically different effects in the short and long run […], when an action has one set of consequences locally and a very different set of consequences in another part of the system [… and] when obvious interventions produce non-obvious consequences. (2007, p. 71)

Senge believes that dynamic complexity is the source of most problems and that the key to understanding it is the identification of patterns and relationships in variables. Unlike the variables in detail complexity, the variables in dynamic complexity are interdependent and difficult to separate. Since most problem-solvers look at problems in terms of brief snapshots in time and in a relatively linear manner, finding the actual source of an issue is problematic. From Senge's perspective, individuals should view a dynamic problem in a holistic manner with a systems approach.

Senge also believes that the dynamic nature of these problems requires organizations that excel at learning. Complex and dynamic systems require cross-functional teams made up of "people who need one another to act" (2007, p. 219). The centerpiece of this effort is "collaborative learning," in which teams engage in open dialogue and explore complex issues from many perspectives (2007, p. 221). Senge identifies three critical dimensions for team learning in organizations: 1) think insightfully about complex issues, 2) utilize innovative, coordinated action, and 3) understand the roles of team members on other teams (2007, p. 219). A key impediment to the use of the systems approach is the existence of defensive routines that blur the facts or the reality of the situation. Effective teams can nullify these defensive routines by embracing conflicting ideas and by ensuring the free flow of information, both bad and good.

The common theme within each perspective is that complexity occurs in many different environments and situations but mainly in moving or dynamic systems in which adaptation occurs in subtle and non-linear ways.

C. Complexity in Programs

Both Kauffman (1993) and Simon (1981) view the outer environment as the primary source of complexity. In a similar manner, Marco Iansiti (1995), the author of "Technology Integration: Managing Technological Evolution in a Complex Environment" views a complex product as the adaptation to "requirements from an organization's existing environment" (p. 521). A product is the result of the fusion of technical concepts and existing knowledge within an organization. In his view, complexity in new product development originates from the requirements, sources of knowledge, and processes that lead to the creation of the product itself (p. 522). For a comprehensive discussion of a Complex Product System, Mike Hobday (1998), the author of *Product Complexity, Innovation and Industrial Organization*, provides a clear definition and a list of factors that contribute to product complexity.

Hobday (1998) defines a complex product or system as "any high cost, engineering-intensive product, sub-system, system or construct supplied by a unit of production" (p. 2). Many of these complex products are the result of new and emerging technology and involve "high levels of uncertainty and risk" (p. 5). Hobday also provides a list of interdependent product dimensions that characterize complex products. These factors include:

- Unit cost/financial scale of project,

- Product volume,
- Degree of technological novelty,
- Extent of embedded software in the product,
- Quantity of sub-systems and components,
- Degree of customization of components,
- Complexity and choice of system architectures,
- Quantity of alternative component design paths,
- Feedback loops from later to earlier stages,
- Variety of distinct knowledge bases,
- Variety of skills and engineering inputs,
- Intensity of user involvement,
- Uncertainty/change in user requirements,
- Intensity of other supplier involvement, and
- Intensity of regulatory involvement. (Hobday, 1998, p. 10)

These product dimensions increase the difficulty of coordination and systems architecture, and they make coordination among contributing stakeholders an essential element of success.

Robert W. Rykroft and Don E. Kash (1999) discuss complexity in product development in their book *The Complexity Challenge: Technological Innovation for the 21st Century*. Rykroft and Kash define technological complexity as "any technology that could not be understood in detail by an expert individual" (1999, p. 54). They provide several conceptualizations of product complexity that include the number of components in a system, the "relationship between process and product technologies," and the use of feedback loops to self-adjust or self-correct system attributes known as cybernetics (1999, p. 55). They describe the complex systems emerging from technological innovation as a combination of craft production and mass production that are characterized by a "high degree of risk and uncertainty, a constant sense of novelty, a drive to solve new problems, and above all, a lot of trial-and-error searching and non-linear learning" (Rykroft & Kash, 1999, p. 28).

The sense of novelty that characterizes the development of complex systems means that learning organizations must have a core competency in accumulating and transferring information as well as a proven process to reflect on new information (1999, p. 62). The pressure of meeting a time-to-market requires the organization to employ "error-embracing behavior" in order to gain insights on complex systems during their development (1999, p. 63). However, error-embracing behavior does not produce substantial improvements in time-to-market unless organizations understand the importance of communication throughout the organizational network.

These perspectives provide similar discussions on complex product characteristics, the use of feedback loops, self-correcting systems, and non-linear learning. The drive to field these complex systems at a faster rate while adapting to a changing environment requires a seamless relationship between technology and the organization.

1. Characteristics of Management Systems

Numerous models provide a framework for creating a new product and managing its development. Roy C. Rothwell (1992), in his article "Successful Industrial Innovation: Critical Factors for the 1990s," provides a useful description of five generations of innovation processes, starting in the 1960s. The first two generations of models describe "technology-push" and "need pull" as linear and sequential models of development (1992, p. 221). The third-generation model continues the use of a sequential process, but it also included the use of feedback loops. The fourth-generation model of the 1980s went to the use of a parallel process to cut down on cycle-time and emphasized integration between R&D and manufacturing. The fifth-generation model of the 1990s included the use of parallel processes and systems integration, with an emphasis on collaboration among organizations (Rothwell, 1992, p. 221).

Although Hobday did not differentiate the five generations of industrial innovation, he concurred with Rothwell that complex products and systems do not follow the “conventional model” of development (Hobday, 1998, p. 18). He emphasized that the key difference between complex products and systems and simple systems was user involvement because such systems were “individually developed and tailored […] for a particular customer” (Hobday, 1998, p. 19). Rykroft and Kash (1999) strongly endorse the importance of strong collaboration between the user and the system developer.

Rykroft and Kash contend that the use of the linear model works well with mature technology in a mass-production environment but is ill-suited for the development of tailored, complex systems because it detracts from rapid decision-making (Rykroft & Kash, 1999, p. 59). The user and marketplace demand for complex technology requires a faster cycle-time using non-linear concurrent models. These models accentuate collaboration among many different organizations, firms, and agencies and “error-embracing behavior” (1999, p. 63). To reduce cycle-time, Rothwell identified a number of factors that influenced a “time-based strategy,” including those listed below.

- Adequate preparation: careful project evaluation, analysis, and planning, as well as gaining the commitment of those who will be involved in the project,
- Efficient indirect development activities: project control, administration, and coordination 50% of total project time,
- Adoption of a more horizontal management style with increased decision-making at lower levels,
- Efficient upstream data linkages and an inter-company liaison: involving primary suppliers at an early stage of development,
- Use of integrated teams during development and prototyping,

- Modification of the development process: maximizing the use of simulation models through the use of expert systems,
- Incremental improvement strategy: continuous improvements of existing products,
- Carry-over strategies: use of significant elements of earlier models in the most recent designs,
- Designed-in flexibility: creation of flexible designs,
- Fuller organizational and systems integration: minimizing the number of reporting layers, and
- Fully developed internal database (1992, p. 234-235).

Although Rykroft and Kash contend that the linear model is inadequate for innovating complex technology, they admit that the non-linear and dynamic system is crisis-oriented and messy. They apply the term "self-organizing" to the description of networks of leaders, knowledge workers, and groups who share risk and information across organizational boundaries (Rykroft & Kash, 1992, p. 90). The second pillar, "evolutionary learning," is the imperfect and messy process of integrating and testing components while applying knowledge to keep pace with technological progress (1992, p. 135).

While Rykroft and Kash impart a conceptual perspective on the management of complex products and systems, Iansiti offers some best practices for technology integration. Like most of the authors mentioned, he subscribes to a systems approach as the best means of problem solving and decision-making, and he points out that the most important period of a technology integration project is during project specification. During this stage, he accentuates the importance of a broad and informed approach to framing problems and searching for solutions through multiple contexts (Iansiti, 1995, p. 525).

Several authors emphasized the crisis-oriented approach to the development of complex products and systems. While the non-linear approach may cut down on cycle-time, it requires several critical inputs—such as a high degree of trust among organizations, risk acceptance, and capturing and disseminating knowledge to stakeholders in a timely manner. The next section highlights several of the potential problem areas that programs encounter when they manage complex systems using a non-linear approach.

2. Common Managerial Problems with Complex Programs

In his article "Managing Innovation in Complex Product Systems," Howard Rush (1997) identified three "hotspot" categories: 1) requirements identification, 2) coordination of information, and 3) process issues (p. 4/2). The considerable time pressures that differentiate complex products and systems often lead to inadequate system requirements that necessitate later revision. The intensity of organizational coordination in complex products and systems also requires the diffusion of explicit and tacit knowledge—a typical coordination issue. Another problem that permeated these types of programs is the lack of adequate staffing due to the exigent nature of the program's formation. The lack of staffing is a potential cause of short cuts taken in processes and best practices (Rush, 1997).

Although several of the authors advocated following a less linear and sequential model of development for complex products and systems, they all advocated following some type of process. Nelson P. Repenning (2001) discusses the potential impact of not following a process during new product development in his paper "Understanding Fire Fighting in New Product Development." In the context of product development, Repenning describes fire fighting as the "unplanned allocation of engineers and other resources to fix problems discovered late in a product's development cycle" (2001, p. 5). He believes that dedicating a large number of resources to fighting fires takes away valuable resources from other critical project activities. He attributes the persistent fire-fighting mentality to organizations that do not possess an in-house capability for organizational learning. These organizations also fail to allocate resources, and they attribute the cause of their problems to the "attitude and disposition of the people working within the process rather than to the structure of the process itself" (2001, p. 25).

3. Applying the Systems Approach

A common theme in this literature review is that most complexity problems are dynamic in nature. "Systems thinking" is a holistic approach to understanding and comprehending the many variables present in dynamic situations. Senge fully advocates the adoption of systems thinking when he says,

> [W]e tend to focus on snapshots of isolated parts of the system, and wonder why our deepest problems never seem to get solved. Systems thinking is a conceptual framework, a body of knowledge and tools that has been developed over the past fifty years, to make the full patterns clearer, and to help us see how to change them effectively. (2007, p. 7)

As a conceptual framework, the systems approach attempts to make sense of systems that have many interrelated parts. During product development, the practical means of realizing the systems approach is through the discipline known as systems engineering. During the post-World War II period, systems engineering emerged as a means to develop solutions to dynamic problems. Systems engineering takes the insights gained from systems thinking "with an orientation toward the engineering and analysis of technical systems" (Blanchard & Fabrycky, 2006, p. 19).

The Institute for Electrical and Electronics Engineers (IEEE) defines systems engineering as "an interdisciplinary collaborative approach to derive, evolve, and verify a lifecycle balanced solution which satisfies customer expectations and meets public acceptability" (1994, p. 11). The International Council on System Engineering (INCOSE) defines systems engineering as

> an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, and then proceeding with design synthesis and system validation while considering the complete problem. Systems Engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs. (2006, June, p. 1.18)

The *Defense Acquisition Guidebook* defines systems engineering in this way:

> Systems engineering is the overarching process that a program team applies to transition from a stated capability need to an operationally effective and suitable system. Systems engineering encompasses the application of systems engineering processes across the acquisition lifecycle (adapted to each and every phase) and is intended to be the integrating mechanism for balanced solutions addressing capability needs, design considerations and constraints, as well as limitations imposed by technology, budget, and schedule. The systems engineering processes are applied early in concept definition, and then continuously throughout the total lifecycle. (DoD, 2008, p. 4.1)

The common theme among these definitions is the focus on meeting a user's needs through an interdisciplinary approach to solving technical problems with a lifecycle orientation.

In accordance with the *DoD Directive 5000.1*, *The Defense Acquisition System*, the use of the systems engineering process is the official policy of the DoD, and it will "optimize system performance and minimize total ownership costs" (Under Secretary of Defense (AT&L), 2003a). The DoD program manager is empowered to develop a tailored systems engineering approach for a particular program that will integrate systems engineering processes throughout a product's lifecycle.

4. Use of Risk Management

Simon described the difficulty of rational decision-making under uncertainty when he said, "reasonable men reach reasonable conclusions in circumstances where they have no prospect of applying classical models of substantive rationality" (Simon, 1978, p. 14). Complex programs that are unable to manage complexity and uncertainty will quickly fall into a resource-intensive fire-fighting mode (Repenning, 2001).

Complex programs must adapt to an outer environment that consists of a large number of risk factors and considerations that are interrelated. Ultimately, this leads to an environment of uncertainty and ambiguity. Programs categorize risk as either internal or external. In the article, “On Uncertainty, Ambiguity, and Complexity in Project Management,” Pich, Loch and DeMeyer expressed uncertainty and ambiguity in terms of “information adequacy” (2002, p. 1008). External risk is more difficult to mitigate and often falls into the category of “unknown-unknowns” (Pich et al., 2002, p. 1019). Ambiguity is an unknown-known, and it occurs when a program lacks awareness of a particular problem but is able to improve the availability of information about the unknown through the expenditure of resources (2002, p. 1013). This is in contrast to “unknown-unknowns” that exist and exert a significant impact on complex programs but are completely unforeseen by a program manager (2002, p. 1019).

The proactive and consistent management of risk is an essential element of successful projects (PMI, 2004, p. 240). The risk management process assumes that problems are recognizable through the early identification of signals that indicate a potential problem. *The Risk Management Guide for DoD Acquisition* defines risk as “a measure of future uncertainties in achieving program performance goals and objectives within defined cost, schedule, and performance constraints” (DAU, 2006, August, p. 1). Furthermore, it organizes risk into three components: 1) a future root cause, 2) a probability or likelihood, and 3) a consequence or effect (2006, August, p. 1). *The Risk Management Guide for DoD Acquisition* emphasizes the use of risk management throughout a program’s lifecycle by suggesting a strong integration with the systems engineering and test and evaluation processes. *The Risk Management Guide* also identifies several common risk-related attributes to successful programs:

- Feasible, stable, and well-understood user requirements, supported by leadership/stakeholders, and integrated with program decisions;
- A close partnership with users, industry, and other stakeholders;
- A planned risk management process integral to the acquisition process, especially to the technical planning (SEP and TEMP) processes, and other program-related partnerships;

- Continuous, event-driven technical reviews to help define a program that satisfies the user's needs within acceptable risk;
- Identified risks and completed risk analyses;
- Developed, resourced, and implemented risk mitigation plans;
- Acquisition and support strategies consistent with risk level and risk mitigation plans;
- Established thresholds and criteria for proactively implementing defined risk mitigation plans;
- Continuous and iterative assessment of risks;
- The risk analysis function independent from the PM;
- A defined set of success criteria for performance, schedule, and cost elements and a formally documented risk management process. (DAU, August, 2006, p. 5)

Every program has some element of risk whether its managers know it or not, and it is the basic responsibility of any manager of a complex program to manage risk. A major determinant to a program manager's ability to manage risk is the program's strategic approach.

5. Strategic Planning

Complex programs require a significant degree of coordination and synchronization to achieve their managers' objectives and overcome ill-structured problems. Approaching ill-structured problems requires the program manager (PM) to engage in a process known as strategic planning. Simon (1976) described strategy as a "time binding" process in which "a series of decisions determine behavior over a certain stretch of time" (p. 67). Porter (1996) discussed strategy in terms of different and unique positioning. He defined strategy as "the creation of a unique and valuable position, involving a different set of activities," which involves positioning a "tailored set of activities" (p. 68). Porter also stated that the "essence of strategy is choosing what not to do" (1996, p. 70).

Porter emphasized three types of “fit” for an organization: 1) simple consistency, 2) reinforcing, and 3) optimization of effort (1996, pp. 71-73). Consistency occurs when an organization communicates a common message, and the organization’s activities reflect a “single-minded” approach to meeting objectives (1996, p. 71). The reinforcement of fit occurs when activities strengthen and build on one another—similar to the manner in which risk management reinforces systems engineering (1996, p. 72). The optimization of effort occurs when an organization’s activities are coordinated and minimize the amount of wasted effort. While strategies consist of many interrelated activities, it is essential to keep in mind that the whole matters more than the any individual part (1996, p. 73).

In terms of complex acquisition programs, the Defense Systems Management College (DSMC) defines strategy as a “framework for planning, organizing, staffing, controlling, and leading a program,” that is designed to “achieve program objectives within specified resource constraints” (1999, p. 1-1). Programs also tailor strategies to the goals, objectives and customer or user expectations with the goal of achieving resilience and stability over time (Porter, 1996, p. 66; DSMC, 1999, p. 1-1, 1-2). Strategy is also a means for program leadership to set clear priorities, integrate program activities, and serve as a decision-making aid for individuals throughout the organization (Porter, 1996, p. 69; DSMC, 1999, p. 1-4).

Specific to defense programs, there are five characteristics to acquisition strategy: 1) realism, 2) stability, 3) resource balance, 4) flexibility, and 5) managed risk (DSMC, 1999, p. 2-1). Changes to an acquisition strategy often result in changes to a program’s overall risk level, and therefore, the project leadership must flexibly adjust the acquisition strategy to changes in the environment (1999, p. 2-7). The acquisition strategy should also serve as a guide for program stakeholders on how the program will operate in all phases of a product’s lifecycle (1999, p. 3-10).

D. Conclusion

The purpose of this chapter was to provide a theoretical framework for this case study, with a focus on complexity. Complex programs, particularly those using a time-based strategy of fielding, require a unique set of considerations to achieve success. The MGS clearly falls into the category of a complex system, and the MGS program certainly embraced a dynamic self-organization to adapt to the outside environment. The next chapter provides a context to the outer environment of the Stryker program.

III. The Road to Stryker

A. Introduction

> We [the Army] discovered that most of our heavy equipment, in a country that was wrestling to reestablish itself economically, tore their roads up so badly that commerce could not get through. And then we had to come back in and repair those roads. (as cited in Hillen, 2000)

General Eric Shinseki's observation could describe any number of situations in Iraq or Afghanistan. However, General Shinseki's comment describes road conditions encountered in Bosnia in 1997. As the Chief of Staff of the Army (CSA) from 1999–2003, it was his responsibility to set the Army's azimuth and ensure that the Army could meet all of its obligations in accordance with the *National Security Strategy* and *National Military Strategy*. For General Shinseki, the fundamental problem was to determine what the Army should be for the next 30 years. Through this exercise, he identified a clear capability gap between the evolving strategic environment and the Army's existing capabilities (Hillen, 2000).

To close this gap, he initiated a transformational strategy for the Army that he anticipated would last from 1999 to 2030. Sustaining this long-term strategy required a series of incremental changes to provide "irreversible momentum" (Shinseki, 2003). Embedded within Army Transformation was the implementation of the Interim Force (renamed the Stryker Brigade Combat Team in 2002), which ultimately served as the catalyst and initial increment of Army Transformation (Shinseki, 2001, p. 12).

The purpose of this chapter is to understand the origins of the Mobile Gun System as part of Stryker. The background includes a description of the evolving strategic environment of the 1990s, the strategy of Army Transformation, the Interim Force operational requirements, and the subsequent selection of the materiel solution for the Interim Armored Vehicle (IAV) requirement.

B. Strategic Context: An Uncertain and Volatile Environment

The end of the Cold War brought an increase in small-scale contingencies that intensified the demand for ground-force commitments. Fiscally, the decreasing size of defense budgets constrained fiscal resources and forced a more disciplined prioritization of effort. Economically, the United States experienced a prolonged period of growth that enabled an intensive investment in private-sector research and development and led to an increasingly integrated global community. Technologically, the availability of information technology was rapidly improving the availability of relevant and real-time information. The Army found itself on a new playing field, yet it still had the same doctrine, organization, and culture as it had in the Cold War period. The next section discusses the increase in small-scale contingencies and the Army's structural misalignment.

1. A New Focus on Small-scale Contingencies

Throughout the 1990s, unpredictable events caused the United States to place the Army into a number of potentially disastrous situations such as early Desert Shield in 1990, Somalia in 1993, Haiti in 1994, Bosnia in 1997, and Kosovo in 1999. A rapid commitment of ground forces to remote regions characterized these deployments. An example of a potentially disastrous situation occurred shortly after Iraq's invasion of Kuwait in August 1990. The US lacked a medium-force that could rapidly respond to an Iraqi invasion of Saudi Arabia, and it committed the lightly equipped 82nd Airborne Division as a stopgap measure. The Army essentially "held its breath" as this unit secured the border against several divisions of Iraqi armor until heavy US units arrived (Hillen, 2000). Several years later, a company of Rangers incurred heavy casualties while operating without the benefit of armored vehicles in the congested streets of central Mogadishu. Soon thereafter, the deployment of heavy armor, such as M-1 tanks, to the Balkans was restricted due to the narrow roads and weight-restricted bridges in the region.

Concurrent with the increase in small-scale contingencies was the growing prevalence of information technology. The availability of information technology allowed sub-national and transnational groups to improve their ability to communicate and coordinate their efforts (Shinseki, 2001, p. 4). The multi-polar international security environment was increasingly vulnerable to the criminal and terrorist elements that used asymmetric tactics to achieve their limited objectives.

These examples demonstrated a pattern of contingency deployments to geographically remote areas under uncertain political and operational conditions. During the 1990s, United States reduced the size of the Army from 781,000 to 479,426, despite the Army's role as the nation's primary "military to military engagement tool for influencing policies and actions of other nations" (Shinseki, 2001, p. 2). The smaller Army was clearly stretched, and its operational tempo increased from one deployment every four years to one deployment every fourteen weeks following the collapse of the Berlin Wall in 1989 (Shinseki, 2000, p. 22).

General Shinseki saw the Army's contribution to stability as "peacetime engagement, crisis management, deterrence, and the kind of rapidly deployable, overwhelming combat power that enables such capabilities" (Shinseki, 2000, p. 22). His ladder of inference pointed towards an impending crisis on the nation's strategic horizon.

2. Dealing with Army Structural Misalignment

These developments revealed a structural gap in the Army's capabilities. Simply put, the Army organized itself for either "high-end" or "low-end" conflict (Shinseki, 2000, p. 23). The decreasing emphasis on high-intensity conflict and the prevalence of small-scale contingencies urgently necessitated a force optimized for these conditions—specifically a force that fell in a "medium" range between the existing high- and low-end formations.

Ten years after the end of the Cold War, the Army retained a mix of heavy and light "Legacy" formations that it had organized on the Cold War paradigm. The light formations were capable of rapid deployment, but they lacked sufficient lethality, survivability, and mobility to engage a more heavily equipped adversary.

On the other hand, the heavy formations were extremely lethal and survivable, but they depended on enormous transportation assets that required well-developed airfields and seaports at the destination point. The Army lacked a medium capability that could provide a mix of heavy and light capabilities. To address this urgent situation, General Shinseki initiated Army Transformation.

C. The Vision: Initiate Irreversible Momentum

General Shinseki was concerned that the Army could potentially become irrelevant if it did not adapt to the changing environment. Its current force structure was difficult to deploy and, in many ways, was a liability.

1. General Shinseki's Ladder of Inference

Recognizing the Army's shortcomings, General Shinseki initiated changes that led to a force that could dominate the full spectrum of conflict, not just the high and low ends. He saw the next major contingency occurring in a place like Central Asia or East Timor, not the North German Plain. General Shinseki underscored how important it was to change the Army when he stated:

> Frankly, the magnificent army that fought in Desert Storm is a great army […]. But it was one we designed for the Cold War, and the Cold War has been over for ten years now. As we look forward to the next century, we've seen a bit of what that next century is going to look like, and the kinds of deployments we've had in the last ten years. (as cited in Hillen, 2000)

General Shinseki was also concerned that the Legacy Forces were overly dependent on predictable air and sea debarkation points that were easy targets for a future adversary. Consequently, he made it a requirement to insert an Army brigade anywhere in the world, including austere airfields, within 96 hours (Shinseki, 2000, p. 28). The end state of the Army's Transformation was the Objective Force, later known as the Future Combat System (FCS). Through Army Transformation, the Objective Force would be operational starting around 2010. To hedge the capability gap, General Shinseki modernized the Legacy Forces, and created the Interim Force. General Shinseki's ladder of inference created a tremendous sense of urgency for change. The ladder of inference forced him to confront the brutal fact that the Army faced potential irrelevance if it did not close the medium-force capability gap (see Figure 2).

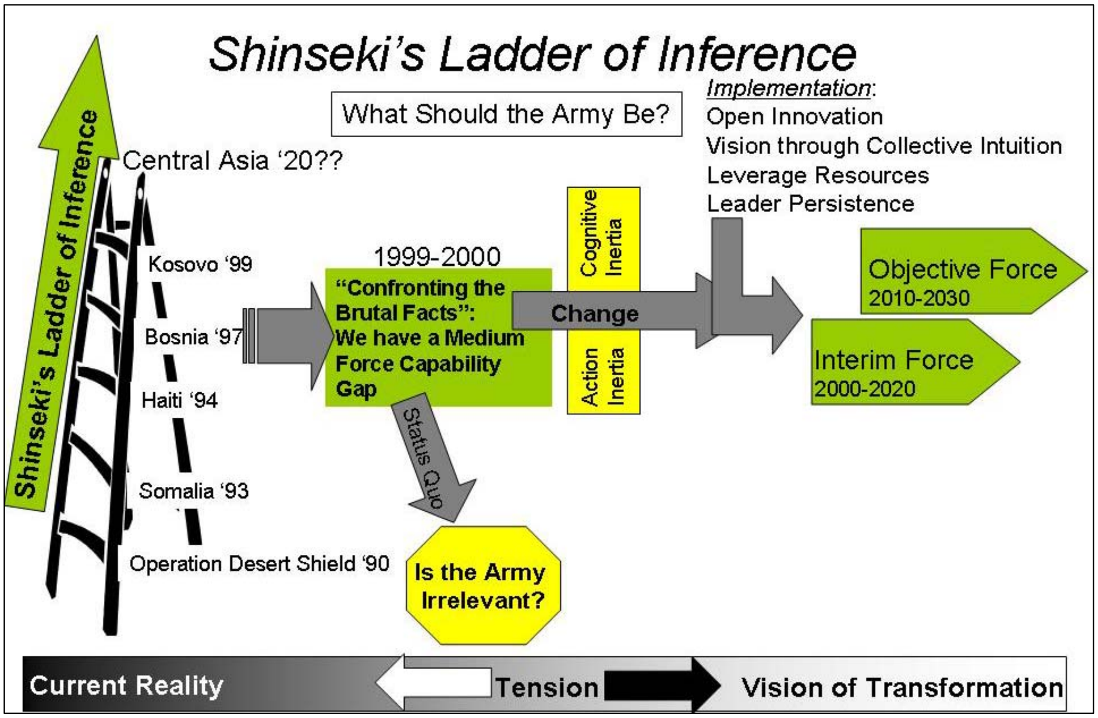


Figure 2. The Urgency behind the Interim Force Caused by the Medium-force Capability Gap

2. A Time-based Change Strategy

The purpose of the Interim Force was to serve as the bridge between the current capabilities and the Objective Force. The Interim Force would provide the medium-force capability, as well as insights on doctrine, organization, and technology for the Objective Force (Shinseki, 2000, p. 28). The Interim Force was also the vital link for General Shinseki's change strategy, and he placed command emphasis on its urgency. With a four-year time horizon as the CSA, General Shinseki understood that the Interim Force concept was the foothold for Army Transformation. In a later interview with PBS *Frontline*, General Shinseki said,

> In my case, the appointment is for four years. As I've looked back at the tenures of other chiefs, generally the good ideas that found their way into implementation are the ones that were begun early […]. I just believe that I've got to get the momentum early. That's important to transformation, and my contribution to wherever transformation ends up happening is providing that momentum so that future chiefs can build on it […]. Generally, it's the first two years that'll make the difference. (as cited in Hillen, 2000)

The urgent nature of the capability gap necessitated the selection of an Interim Armored Vehicle (IAV) that was immediately available. The urgent nature of the threat and his ability to transform the military necessitated the adoption of a time-based transformation strategy. General Shinseki stipulated that this vehicle be an "off-the-shelf system" for procurement in FY2000 (Shinseki, 2001, p. 12). According to Lieutenant General Paul J. Kern, the Military Deputy to the Assistant Secretary of the Army for Acquisition, Technology and Logistics at the time of the IAV selection, General Shinseki continuously pushed the Army to move faster with the selection of the materiel solution for the IBCT (Federal News Service, 2000).

Furthermore, General Shinseki's four-year time horizon as the Chief of Staff of the Army played a critical role in driving the IAV schedule, and he provided highly detailed direction over decisions that might have an impact on its success. This oversight included the review and approval of the IAV Request for Proposal (RFP) (Baumgardner, 2000, April 7).

General Shinseki's time horizon as the CSA acted as the upper parameter for the Mobile Gun System's development schedule. Within the IAV Source Selection Plan, originally published in March 2000, the time for those vehicles requiring "extended variant/configuration development" was not to exceed 24 months, which included government testing (Kern, 2000). In effect, the developmental strategy for the MGS was time-based, not event-based, from the very beginning.

The intent of the Interim Force concept was to have a combat formation that was packaged at the Aerial Point of Embarkation (APOE) and immediately available for operations upon arriving at its destination (PM SBCT, 2000, p. 11). That capability provided the Army with a unique ability to place a large, well-equipped force deep into a threat environment. The Interim Force could use operational maneuver to go where it was least expected while having the capability to sustain itself and fight. General Shinseki, however, had a holistic view of Transformation, and it clearly encompassed more than just a new vehicle. He said:

> As we talk about transformation, we intend to get into the design of our units […]. As we reduce the size of our platforms, we also reduce the size of this rather significant logistical footprint, and that gives us the kind of agility that will put us in places that are least expected. We can reduce our predictability and get in there faster. (as cited in Hillen, 2000)

His approach was highly aggressive, with an IAV procurement starting in FY2000 and an initial operational capability by FY2002. The unique Interim Force requirements also reflected a change in the way that the government approached acquisition programs.

D. Acquisition Reforms of the 1990s

The IAV program was among the vanguard of programs in the government's effort to revamp and streamline defense acquisition. During the 1990s, the government passed a series of legislative reforms with the intention of aligning defense acquisitions with the market-based model found in the commercial sector. The driver of these changes, Dr. William J. Perry, the Secretary of Defense from 1994–1997, wanted to access commercial industry, move away from a separate defense industry, achieve near-term cost savings, and capitalize on the technology advances of the commercial sector ("DoD News Briefing," 1995).

The primary components of the legislative reform of the government's acquisition system were the *Federal Acquisition Reform Act* (*FARA*), the *Federal Acquisition Streamlining Act* (*FASA*), and the *Services Acquisition Reform Act* (*SARA*). The streamlining of government acquisition regulations also allowed for a considerable downsizing of the government's civilian acquisition workforce.

1. Use of Performance Specifications over Government Specifications and Standards

One of the more significant elements of these acquisition reforms that affected the IAV program was the reduction or elimination in processes for specifications and standards. Previously, the government relied on a wide range of military specifications (MilSpec) and military standards (MilStd) to guide the contractor on what processes and materiel to use in developing and producing a system. *The Defense Standardization Program Policies and Procedures* (*DoD 4120.24-M*) defines a defense specification as “a document that describes the essential technical requirements for purchased materiel that is military unique or substantially modified commercial items” (Under Secretary of Defense (AT&L), 2000, p. 67).

The purpose of the specification and standards reform movement was to allow the contractor to exercise more initiative, infuse innovation into product development, and shift to a performance-based specification. In relinquishing some elements of design-oversight and allowing the commercial sector to find the materiel solution, the challenge for the government was how to “clearly describe technical requirements and provide sufficient verification to assure that products meet the users’ needs” (Millett & Gillis, 1998, p. 72).

2. Use of Non-developmental Items (NDI) and Commercial Off-the-shelf (COTS)

With a drive for a peace dividend following the end of the Cold War, the DoD had fewer funds available for research and development. The decrease in research and development funding required the DoD to look towards the private sector for products and services that were immediately available. The DoD termed these items as either Non-development Items (NDI) or Commercial Off-the-shelf (COTS).

In a June 2000 report, the Office of the Secretary of Defense (OSD) provided a list of best practices and lessons learned for NDI and COTS. The report defined a COTS item as:

> one that is sold, leased, or licensed to the general public; offered by a vendor trying to profit from it; supported and evolved by the vendor who retains the intellectual property rights; available in multiple, identical copies; and used without modification of the internals. (Gansler, 2000, July, p. 3)

The DoD aggressively pushed to maximize the use of COTS and NDI to reduce cycle-time, increase the pace of new technology insertion, improve reliability and availability, and lower the total lifecycle costs (Gansler, 2000, July, p. 2). COTS are a subset of NDI and are defined as:

> Items that are used exclusively for government purposes by a Federal Agency, a state or local government, or a foreign government with which the United States has a mutual defense cooperation agreement; and any item described here that requires only minor modifications of the type customarily available in the commercial marketplace in order to meet the requirements of the processing department or agency. (Gutierrez, 2002, p. 66)

While the intent of NDI and COTS was to "simplify and accelerate the acquisition process," the use of NDI and COTS also incurred programmatic risk (Steves, 1997, p. 40). Among the risks associated with NDI and COTS are the 1) form, fit, and function characteristics, 2) ability to adapt interface and data standards, 3) vendor's anticipated and intended use of the NDI and COTS, 4) vendor's test approach, and 5) the government's ability to verify vendor test results (Gutierrez, 2002, p. 68).

3. IAV Request for Proposal (RFP)

When the IAV Program Management Office released the draft RFP in December 1999, it did not contain detailed specifications because the program manager wanted to provide the contractors with the maximum amount of flexibility in tailoring their proposals (Dawson, 2001, p. 56). The final RFP, published in April 2000, contained a performance-based Statement of Work (SOW) founded on the Operational Requirements Document (ORD); it also contained only seven government specifications and standards (Dawson, 2001, pp. 76, 95). The final RFP also allowed the possibility of awarding separate contracts for the Infantry Carrier Variant (ICV) and for the Mobile Gun System variant (Baumgardner, 2000, April 10).

The government presented four alternatives for contract awards in the RFP: 1) one award for the ICV variants and MGS variant, 2) one award for ICV variants and one award for the MGS, 3) one award for the ICV variants only, or 4) one award for the MGS only (Gamboa, 2001, April 9, p. 4).

Working closely with the materiel developer, the Training and Doctrine Command (TRADOC) conducted a parallel effort to develop the operational requirements. Although the government could request a waiver to use military specifications and standards through the Milestone Decision Authority (MDA), the waiver process was long and generally discouraging because the DoD was trying to move away from the old ways of doing business. It was not until 2005 that the DoD eliminated the waiver policy to increase the program manager's flexibility to cite military specifications and standards within a solicitation or contract (Kratz, 2005).

E. A New Approach: Interim Force Requirements

The Interim Force requirements reflected the ambiguous and uncertain threat model of the 21st century. The Army chose a new and innovative path to the Interim Force when it transitioned from a threat-based to a unit-based approach to requirements. The next section discusses the transition of requirements concepts, the Stryker operational tenets, and the source selection.

1. Transition from Threat-based to Unit-based Requirements

In previous armored vehicle acquisitions, the Army developed requirements based on a clearly defined threat. During the Cold War period, the Army could draw on abundant amounts of information about known threat systems. For instance, the Army developed the requirements for the M-1 Abrams Tank and the M-2 Bradley Fighting Vehicle to counter a known spectrum of Warsaw Pact platforms and tactics. Although both vehicles functioned as part of a combined arms team, the Army did not stipulate a requirement for commonality. Additionally, these systems went through a deliberate systems development process that included several iterations of technology insertion (COL Robert Schumitz, PM SBCT, personal communication, January 29, 2009). The Interim Armored Vehicle (IAV) was the Army's first new armored combat vehicle since 1981, and the Army saw an opportunity to improve efficiency and effectiveness with a new approach (Federal News Service, 2000).

The Army designed a new type of brigade from the ground up that it designated as the Interim Brigade Combat Team (IBCT). The Army intended for the Interim Armored Vehicle (IAV) to serve as the common vehicle platform to meet the unit's holistic requirements. The requirements for the Stryker were captured in the Operational Requirements Document, written by the user community and describing the system's intended mission and the anticipated operational and sustainment concepts. The Medium Armored Vehicle Operational Requirements Document (ORD) broadly described the threat in this way:

> Asymmetric warfare focuses whatever may be one side's comparative advantage against an enemy's relative weakness. A defining and distinguishing aim of asymmetric warfare is the creation of conditions where the enemy's relative advantage cannot be applied is degraded or neutralized [sic]. The IBCT [Interim Brigade Combat Team] will be employed worldwide, wherever US interests are threatened. To this end, potential threat forces will be armed with various mixes of increasingly sophisticated weaponry. (Federation of American Scientists, 2000)

The Army determined that it wanted a medium-unit capability that could function in the both the "full spectrum environment" and small-scale contingencies (Federation of American Scientists, 2000). Upon achieving its full operation capability, the Interim Force would prevent the Army from becoming irrelevant through the ability to insert a "credible combat force on the ground anywhere in the world in 96 hours from liftoff" (Panel on Operational Test Design and Evaluation of the Interim Armored Vehicle, 2004, p. 117).

2. Interim Brigade Combat Team (IBCT) Operational Concept

The ORD for the Stryker defines the top-level operational capabilities desired for the IBCT as well as the system-level capabilities for the IAV itself (Panel on

Operational Test Design and Evaluation of the Interim Armored Vehicle, 2004, p. 117). The ORD describes the top-level capabilities of the IBCT:

> As a full spectrum combat force, the IBCT is capable of conducting all major doctrinal operations including offensive, defensive, stability, and support actions. Its core operational capabilities rest upon excellent operational and tactical mobility, enhanced situational understanding, combined arms integration down to the company level, and high dismount strengths for close combat in urban and complex terrain. Properly integrated through a mobile robust C4ISR network, these core capabilities compensate for platform limitations that may exist in the close fight, leading to enhanced force effectiveness. When employed in the operational environment for which it is optimized, the IBCT has the capability to achieve decision as a result of its early entry, shaping, and decisive actions. (Federation of American Scientists, 2000)

The ORD describes the combined arms approach of the IBCT and its maneuver advantages. Unlike the Legacy Forces, the Army intended for the IBCT to be in a combat configuration prior to leaving its air or sea embarkation point. Upon arrival in an area of operations, the Army wanted the IBCT prepared for immediate combat operations.

The Army planned for each of the pieces and parts of the IBCT to operate together for a holistic capability with a focus on the company level. For the user community, this point is essential because the IBCT is a system-of-systems. Although each of the systems can operate individually, when combined, they have a decisive effect through their constellation of capabilities. The ORD discusses the six Key Performance Parameters (KPPs) that serve as the performance drivers for the IBCT. KPPs are:

> Those attributes or characteristics of a system that are considered critical or essential to the development of an effective military capability and those attributes that make a significant contribution to the characteristics of the future joint force as defined in the Capstone Concept for Joint Operations. (Chairman of the Joint Chief of Staff, 2007a, May 1, p. GL-14)

These KPPs provide metrics in terms of threshold and objective values. *The Acquisition Strategy Report for the Interim Armored Vehicle* listed four KPPs:

- Interoperability—possesses an interoperable capability to host and integrate existing and planned C4ISR systems.
- C-130 transportability—is transportable in a C-130 aircraft.
- Infantry/Engineer Squad—is capable of transporting and protecting a 9-man infantry or engineer squad.
- Mobile Gun System Bunker Buster—serves primarily as a bunker buster, not as an anti-tank platform. (PM BCT, 2000, p. 14)

The Army developed the Interim Force KPPs as the critical requirements for a family of vehicles that complement one another. The family of vehicles includes ten variants, and the IBCT requires each of these variants to achieve its full capability (see Figure 3).

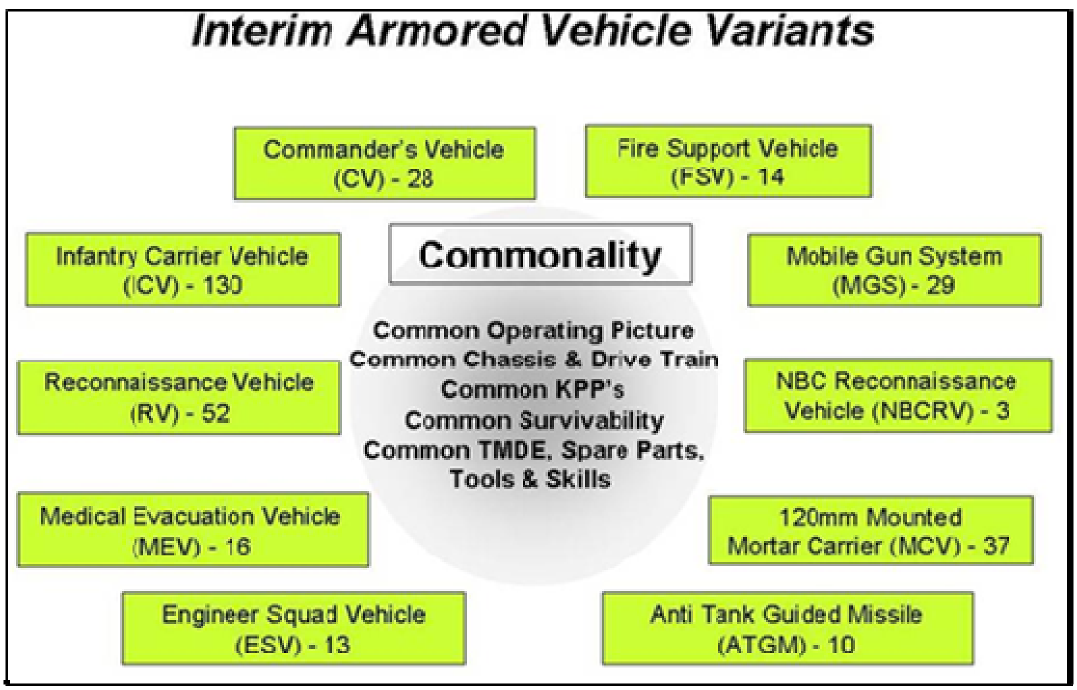


Figure 3. Interim Armored Vehicle Variants
(McCarroll, 2008, slide 4, original chart modified)

F. IAV Acquisition Strategy

In accordance with *DoD Instruction 5000.2*, all acquisition programs require an approved acquisition strategy upon program initiation (DoD, 2008, p. 2.3). The acquisition strategy uses a total systems approach that takes into account all activities that will occur throughout the program's lifecycle (2008, p. 2.3). The program manager is responsible for preparing the acquisition strategy and tailoring it to the program's specific needs and constraints. Additionally, the acquisition strategy serves as a decision aid by

> prioritizing and integrating many diverse functional requirements, evaluating and selecting important issue alternatives, identifying the opportunities and times for critical decisions, and providing a coordinated approach to the economical and effective achievement of program objectives. (DAU, 2003, p. 1-4)

The Army adopted an IAV acquisition strategy that fully supported General Shinseki's charter for a rapidly fielded medium-force that could provide strategic responsiveness. In accordance with General Shinseki's guidance for the Interim Force, the ORD states that, "The initial IBCTs will be populated with systems consisting of integrated off-the-shelf capabilities. Combined with these off-the-shelf systems, innovative applications will enable full operational capabilities for the interim force" (Federation of American Scientists, 2000).

The IAV acquisition strategy was unique in that it covered both developmental and non-developmental efforts. For programs that involve development, a technology development acquisition strategy is normally used. In accordance with the *Defense Acquisition Guidebook*, the technology development acquisition strategy discusses the management of research and development, the number of prototypes, the use of the prototypes in testing, and specific decision points for the user and materiel developer to determine the maturity of a system under development (2008, p. 2.3).

1. Evolutionary Approach

The Army used an acquisition strategy that required the use of NDI to allow for rapid fielding while avoiding any type of long system development. Additionally, the acquisition strategy attempted to execute activities such as "development, production, testing, fielding, deployment, and sustainment" in a concurrent rather than sequential manner (PM SBCT, 2006, March, p. 1). The IAV acquisition strategy adopted an evolutionary acquisition approach. The *DoD 5000.2, The Operation of the Defense Acquisition System* defines evolutionary acquisition as:

> the preferred DoD strategy for rapid acquisition of mature technology for the user. An evolutionary approach delivers capability in increments, recognizing, up front, the need for future capability improvements. The objective is to balance needs and available capability with resources, and to put capability into the hands of the user quickly. The success of the strategy depends on consistent and continuous definition of requirements, and the maturation of technologies that lead to disciplined development and production of systems that provide increasing capability towards a materiel concept. (Under Secretary of Defense (AT&L), 2003b, p. 4)

The evolutionary approach aimed to provide continuous, preplanned improvements to meet current and future capability gaps as technology matured (DoD, 2008, p. 2.3.2). The *Acquisition Strategy Report for the Interim Armored Vehicle* stated the following objectives:

- Emphasize rapid acquisition,
- Incorporate time-phased requirements as appropriate,
- Integrated acquisition and logistics,
- Stress interoperability of the IAVs within and outside the BCT,
- Incorporate Cost as an Independent Variable (CAIV),
- Integrate test and evaluation throughout the process rather than as a final exam,
- Focus on better performance with lower costs and not just on lower costs,

- Stress that system performance should also consider better reliability and quality, and

- Investigate and incorporate technology as appropriate throughout the lifecycle. (PM BCT, 2000, pp. 10-11)

The program initially used the March 1996, *DoD-Instruction-5000.2R* acquisition structure with a Milestone I to III; PM SBCT kept this structure for the MGS and NBCRV until those programs reached their Milestone III (PM SBCT, 2006, March, p. 5) (see Figure 4).

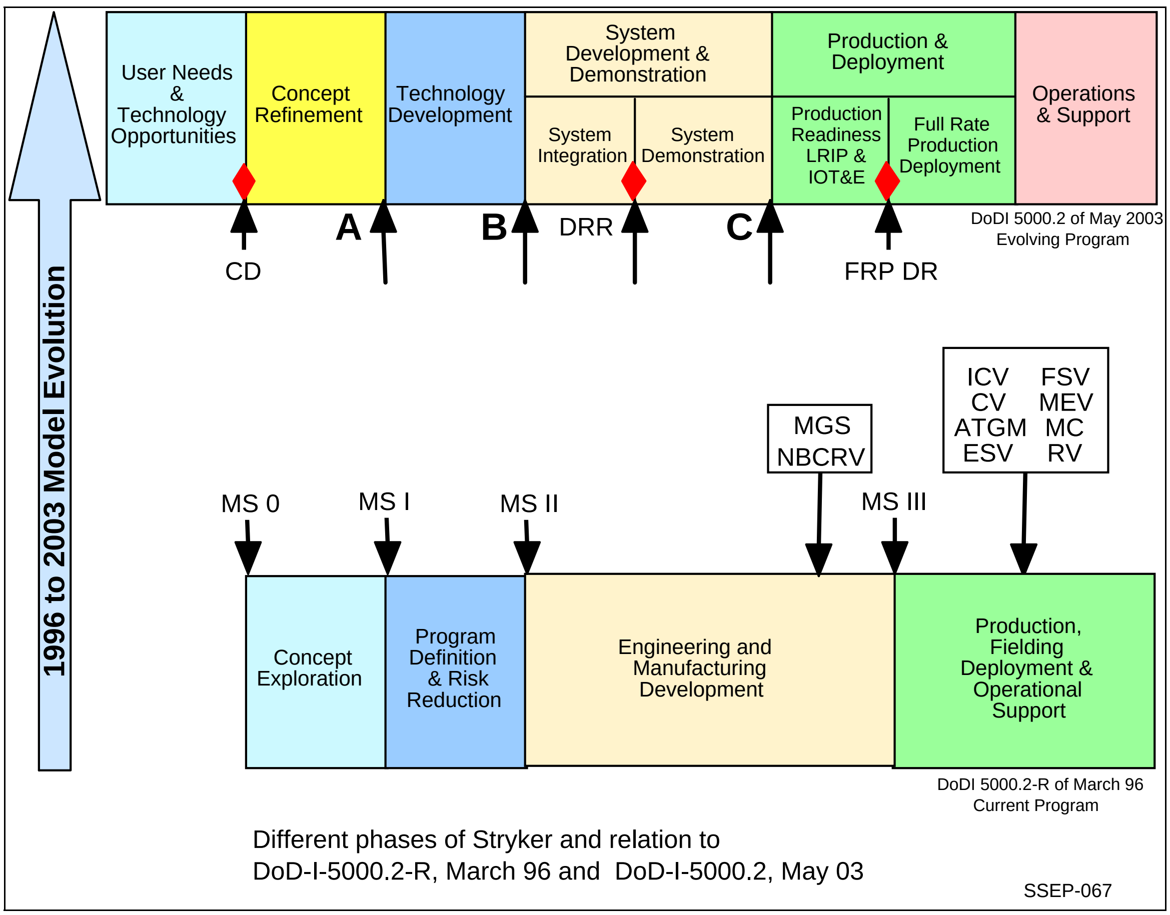


Figure 4. DoD Program Lifecycle Models
(PM SBCT, 2006, March, p. 6)

2. Risk Management

The *Defense Acquisition Guidebook* defines risk management as "the overarching process that encompasses identification, analysis, mitigation planning, mitigation plan implementation, and tracking" (DoD, 2008, p. 4.2.3.5). Additionally, risk management is most effective when the program manager integrates it with a program's systems engineering process "as a driver and a dependency on those processes for root cause and consequence management" (DoD, 2008, p. 4.2.3.5). The IAV acquisition strategy highlighted four areas of risk for the program.

For schedule risk, the acquisition strategy discussed the high probability for "development, test, and production lead times for the MGS" with an initial assessment of red (PM BCT, 2000, p. 23). The program manager's mitigation plan for the MGS development risk was to substitute suitable in lieu of systems until the MGS was available (2000, p. 23).

For technical risk, the acquisition strategy discussed the potential integration issues for the ICV variants with a low probability of occurrence (2000, p. 24). With regard to the ICV, the PM accepted the technical risk.

G. The Materiel Solution for the IBCT

Market research began in earnest with the Platform Performance Demonstration (PPD) held at Fort Knox, Kentucky, from December 1999 to January 2000. During the PPD, the Army hosted 35 candidate platforms from 11 different contractors (Steele, 2000, March, p. 24). The purpose of the PPD was to "determine the potential availability of a family or families of systems to equip a new brigade organization designed for full spectrum operations" (Bell, November 18, p. 1).

The PPD served as a market survey for the Army, not as a competition. Given the NDI acquisition strategy, the PPD also provided insights on the development of the Operational & Organizational Concept and the overarching requirements document. The Army also used it to "evaluate existing systems to determine the state of the art, and see if the performance envisioned for the interim brigades was achievable" (PM BCT, 2000, p. 5). At the close of the PPD, the Army provided each contractor with a written report of their vehicle's potential problem areas (Bell, November 18, p. 3). During the PPD, Major General B.B. Bell, the Armor Center's commanding general at the time, clarified that the PPD was not part of the formal competitive process and that the Army was open to both wheeled and tracked drivetrains (Steele, 2000, March, p. 24).

During the PPD, several companies marketed their designs for the MGS requirement for the IBCT. United Defense marketed its M-8 Armored Gun System, a tracked vehicle that it developed in the early 1990s to meet an armored reconnaissance vehicle requirement for the 82nd Airborne Division. Despite meeting the C-130 transportability requirement and being production ready, the Army cancelled the M-8 program in 1996 because of budget constraints (Light Armored Vehicles, 2008, August 13). General Dynamics Land Systems (GDLS) marketed its Light Armored Vehicle (LAV) III with a turreted 105mm gun that it had previously used as a demonstrator for international markets (LTG (Ret) Joseph Yakovac, personal communication, December 17, 2008). The GDLS variant demonstrated strong potential, but it did not have an auto-loader, an integrated C4ISR suite, a coaxial machine gun or commander's weapon, and fire control modifications to integrate the main gun ammunition (Gourley, 2003, May). All of those components were essential to meet ORD requirements for the MGS.

The PPD was a critical event for developing Non-Developmental Item (NDI) assumptions. The Army assumed that the NDI vehicles could achieve "the system requirements with minimal or no modification" based on the PPD observations (PM BCT, 2000, p. 18). Soon after the PPD, the Army published a Request for Proposal (RFP) on February 29, 2000, and it began a review of the contractor's platforms. The Source Selection Authority (SSA) for the IAV contract was Lieutenant General Paul J. Kern. The SSA served as the "sole authority designated to direct the selection process and make the selection decision" (Kern, 2000, p. 5).

1. Contract Award (November 2000)

Three months behind its original schedule, the Army announced on November 16, 2000, that the General Dynamics Land Systems & General Motors Limited Liability Corporation (GM/GDLS) won the contract award of the ACAT ID IAV vehicle (Hinton, 2001, p. 13). Seven defense contractors had submitted proposals—with two contractors, GM/GDLS and UDLP, submitting several proposals. The proposals were evaluated based on five criteria in order of importance: 1 & 2) schedule and performance (equal), 3 & 4) supportability and cost (equal), and 5) management (Gamboa, 2001, April 9, p. 4). Within the performance area, the Army evaluated a performance requirements element and a commonality element; within the supportability area, the Army evaluated a deployability element, a sustainment cost element, a system maintainability element, and a predicted reliability element (Kern, 2000, p. 9). Although there were a number of individual variants that had superior performance, the Army's desire for commonality took priority. Additionally, commonality took priority over other suitability factors such as reliability.

At the contract award announcement, LTG Kern emphasized that he selected General Dynamics primarily because of the performance, supportability, and commonality that it offered across its ten variants (Gamboa, 2001, April 9, p. 7). This was particularly important to the Army because it decreased the IBCT sustainment and training requirements. Additionally, the Army emphasized the GDLS advantages in protection, vehicle speed, and sustainment cost.

The GM/GDLS based its materiel solution on the Light Armored Vehicle (LAV) III, an 8 x 8, wheeled, armored vehicle. GM/GDLS centered all ten versions of the IAV on the LAV III design, and each had unique mission equipment packages. The LAV III offered a common armored hull, suspension, power pack, drivetrain and associated system (GDLS, 2002, p. 5).

Although the MGS shared the basic chassis with the other nine versions, the Army considered it a separate variant because it required additional developmental work. During the award press conference in November 2000, LTG Kern stated that the “MGS will take the longest [to develop] as it is closest to a full development” (Federal News Service, 2000). The Army initially estimated that the MGS would require approximately two years of developmental work, based on the GM/GDLS proposal. The Army acknowledged that MGS would require integration efforts, but it underplayed this by stating that it did not entail “new guns, sights, or sensor packages for this equipment” (Federal News Service, 2000). The Army considered an extended developmental program, defined as greater than 24 months, as counter to the Army’s Transformation strategy and early fielding of Interim Brigade Combat Teams. Consequently, the Army urged each of the offerors to consider carefully the “probability of success” for meeting the 24-month timeline with their variant proposals (Kern, 2000, p. 12). In this regard, LTG Kern acknowledged that the GDLS MGS schedule was “substantially inferior” to that of the UDLP variant, but he did not view this as unacceptable (Gamboa, 2001, April 9, p. 7).

At the close of the contract award announcement, LTG Kern also stated that there was heavy pressure from higher authority to push for a shorter schedule to enable a full operational capability for the Interim Brigade Combat Team. He said:

> [Y]ou talk to all of our military’s bosses in the Army, General Shinseki, [they say that] we’re too slow. This has been a remarkable trip for all of us, to go from a concept about a year ago. From their perspective [they say], “we [materiel developers] aren’t moving fast enough,” rather than “why didn’t we wait.” We have a capability, which we are trying to get to the field as quickly as possible because it does not exist today. (Federal News Service, 2000)

Although the tracked option proposed by United Defense offered an option that required little developmental work and a faster schedule at a lower cost, the Army made a trade-off based on the limited amount of available information from the PPD and the contractor proposals.

It seems apparent that the Army intended to make the best decision that it could with the limited time and information available rather than make a perfect decision. Given the information available from the PPD and other market research conducted by the materiel developer and user communities, the perception was that the GDLS variants, particularly the MGS, could quickly mature. It is also interesting to note that within the *Acquisition Strategy Report for the Interim Armored Vehicle*, published in March 2000, the Army identified the integration of mission equipment on the ICV as the primary technical risk area (PM BCT, 2000, p. 24). Yet this report did not discuss the technical risk of integrating the more complex components on the MGS or NBCRV, both of which encountered significant challenges with systems integration (2000, p. 24).

2. Award Protest

Soon after the contract award, United Defense, the unsuccessful offeror of the M-113 ICV variant and the M-8 AGS variant, filed a protest. The General Accounting Office upheld the decision to award the contract to GM/GDLS, and it found that the Army's selection of the GM/GDLS ICV and MGS was reasonable (Gamboa, 2001, April 9, p. 7). Within the UDLP award protest, there was considerable discussion on system reliability—a significant problem later encountered with the GDLS MGS. However, the focus of the reliability debate centered on the vehicle chassis, not the unique Mission Equipment Packages (MEP). It is noteworthy that the GDLS MGS was viewed as having significantly superior predicted reliability over the UDLP MGS, mainly because the metric for comparison was Mean Miles Between Critical Failures (MMBCF). The use of this metric did not truly address the uncertainty of the unproven Aries ammunition handling system (AHS) that the GDLS MGS employed.

The award protest delayed what was already a highly compressed schedule by 126 days, and it slowed the program's momentum (Michael Viggato, Deputy PEO GCS, personal communication, December 12, 2008). The Army eventually initiated work on the GM/GDLS contract on April 9, 2001 (Hinton, 2001, p. 13).

H. Conclusion

Despite the protest, the Army successfully initiated the first stage of General Shinseki's plan for Army Transformation. Less than 12 months after General

Shinseki announced his vision, the Army conducted a series of difficult tasks that included the IAV requirements document, PPD & market research, RFP, and source selection. While not a perfect process, the view was that the Army could make necessary adjustments as necessary rather than seek an optimal solution at the expense of time.

The Army demonstrated a willingness to accept some development on the GDLS version of the MGS because of the advantages it offered in commonality and performance. The Army perceived that the GDLS variant of the MGS was close to ready, and it was eager to initiate the program.

IV. The Development of the Mobile Gun System

A. Introduction

As one of the Army's top acquisition priorities, the Stryker had the full support of the Army's senior leadership as well as dedicated fiscal resources, but it also faced the pressures of a time-based acquisition strategy. Unlike other programs, the Stryker consisted of both developmental and non-developmental variants that were under the same acquisition strategy.

The Army immediately fielded eight of the Stryker's variants, while two variants required additional development (MGS and NBCRV). The Army knew that these platforms required the integration of multiple components, and they were operating under the assumption that the MGS would require approximately two years to field (Federal News Service, 2000). At the time of the contract award announcement, this meant that the MGS would complete its development in July 2003.

Coincidentally, this was the same time that the Stryker's "product champion," General Eric Shinseki, would end his four-year tenure as the Army's Chief of Staff. Although this two-year estimate proved to be unachievable, it provided a sense of urgency to the program. The Army continued to push for the rapid development of the MGS because it deemed the MGS as "critical" to meeting the expectations of the combatant commanders (Schuster, 2002, May, p. 19).

As one of the two developmental variants, the MGS encountered a series of unique challenges; this chapter provides an overview of the MGS development. The chapter discusses the MGS Engineering, Manufacturing, and Development (EMD) contract, its characteristics, system requirements, and development events leading up to 2008.

B. MGS Engineering, Manufacturing, and Development (EMD) Contract

The Army selected the GDLS MGS model primarily because of its advantages in commonality and performance, with commonality being the "overriding factor" (Gamboa, 2001, April 9, p. 7). However, during the source-selection process, the Source Selection Case Authority (SSA) believed that the GDLS MGS model presented some schedule risk. In fact, the SSA understood that GDLS "understated" its schedule and that the schedule was "inconsistent with the fundamental terms of the solicitation" (2001, April 9, p. 7).

In reference to the RFP, the government clearly stated that the program's objectives may be achieved through "the acquisition of off-the-shelf, non-developmental items with integration of components, traditional development, [and] systems integration […] staggered over time and across variants" (Gamboa, 2001, April 9, p. 7). However, the RFP stipulated that the Army understood that such an effort should stay within the intent of fielding a system in a timely manner. "[The Government] does not anticipate a lengthy development program and considers extensive development of solutions to be counter to the thrust of this acquisition due to the time, cost and risk associated with such an approach" (Gamboa, 2001, April 9, p. 7).

The Army awarded GDLS a cost-reimbursement contract for EMD that included eight preproduction vehicles for Production Qualification Testing (PQT). The EMD contract used performance-based specifications, and it did not call out the use of a systems engineering process in the statement of work (SOW) (N. Jenny Chang, Tank & Automotive Command Reliability Engineer, personal communication, March 3, 2009). At this point, the government was unable to use any military specifications or standards unless the Milestone Decision Authority (MDA) approved a waiver. Additionally, the MGS did not contain a "design-in" approach for reliability as a requirement in the contract, and this ensured the use of a "test-in" approach during EMD (N. Jenny Chang, Tank & Automotive Command Reliability Engineer, personal communication, March 3, 2009). The EMD contract did not require GDLS to conduct any contractor testing prior to delivery to the government due to time constraints and because Program Executive Office Ground Combat System (PEO GCS) believed that the MGS was close to ready (Michael Viggato, Deputy PEO GCS, personal communication, December 12, 2008). The abbreviated development period necessitated the use of concurrent contractor and government testing with the hope that the vehicles would fare well (Kim McCormick, GDLS PM MGS, personal communication, January 22, 2009).

C. MGS Characteristics and Requirements

The MGS retained the same common armored hull, suspension, power pack, and drivetrain as the ICV variant of the Stryker. Fully combat loaded (without any additional armor), the MGS weighs approximately 47,500 pounds, and a three-man crew consisting of a vehicle commander, gunner, and driver operate the vehicle (GDLS, 2002, p. 7) (see Figure 5).

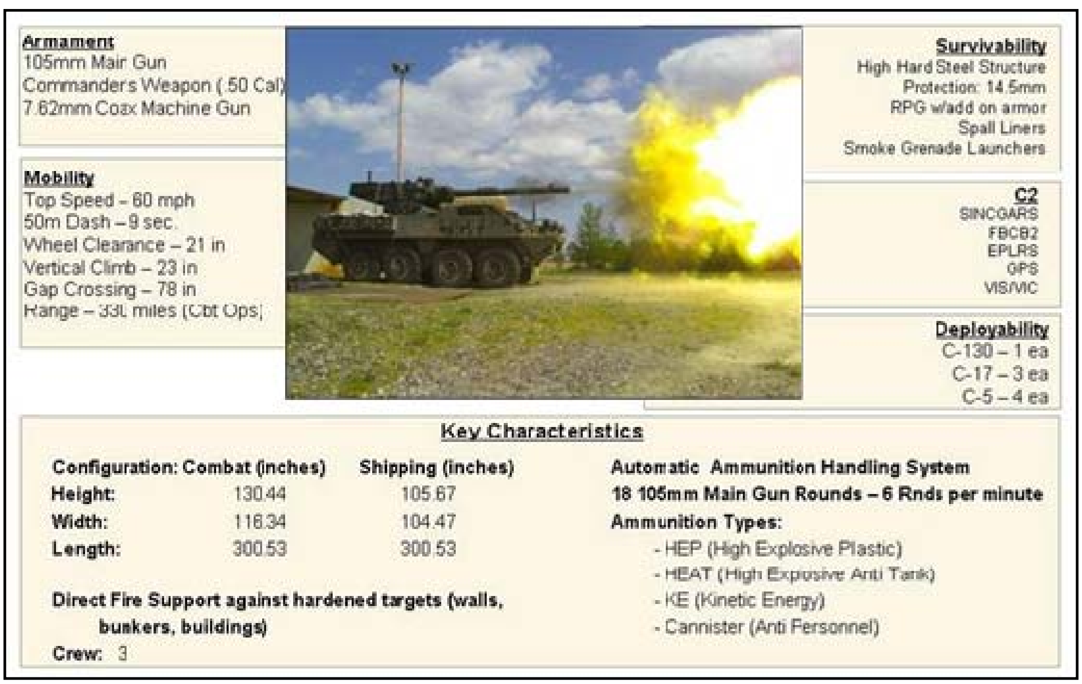


Figure 5. Mobile Gun System Characteristics
(McCarroll, 2008, slide 37)

A Caterpillar 3126A-HEUI diesel engine that uses an Allison MD 3066 automatic transmission powers the MGS, and it has the option of operating in either the 8 x 4 or the 8 x 8 mode. The MGS integrates a Low Profile Turret that houses a similar 105mm main gun, the M-68A2, as the early version of the M-1 tank. The secondary armament consists of a coaxially mounted 7.62mm machine gun and a commander's M-2 .50 caliber machine gun (see Figure 6).

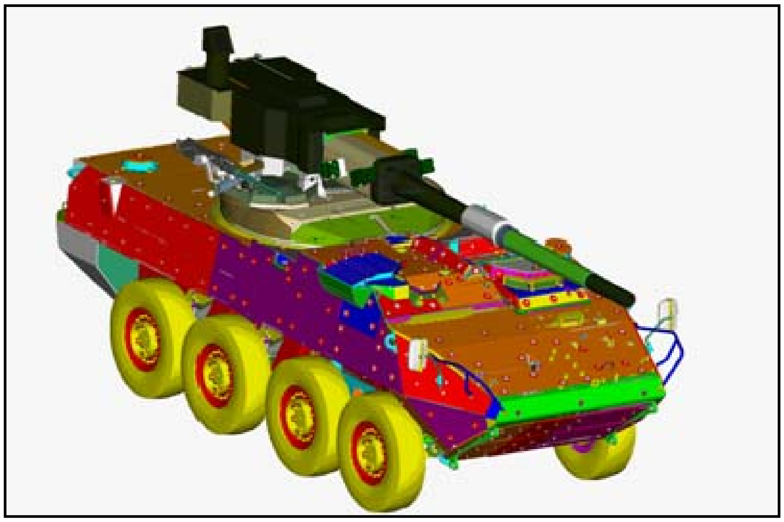


Figure 6. Exterior View of the Stryker Mobile Gun System
(GDLS, 2002, p. 8)

The remainder of this section describes the MGS role within the SBCT; it also describes the system requirements in terms of firepower, survivability, and the command, control, communications, intelligence, surveillance, and reconnaissance (C4ISR).

1. MGS Requirements

Prior to General Shinseki's announcement in 1999 of his vision for the Interim Force, the Army's user community began work on a requirements document for a medium-force. The user community used the insights from the PPD to refine their requirements, and it completed the IAV ORD in March 2000 (PM SBCT, 2008, slide 6). The user community also updated the Stryker ORD as part of the Stryker

Milestone B, and it went for approval by the Joint Requirements Oversight Council (JROC) in February 2004 (Andrews, 2004, slide 13). The JROC has a significant oversight role in the Joint Capabilities Integration and Development System (JCIDS).

The JROC encourages collaboration between the services, ensures that the services develop capabilities in the joint warfighting paradigm, reviews the requirements of programs that may have a joint interest or impact, and validates Key Performance Parameters (KPPs) (CJCS, 2007a, May, p. 2). As of 2008, the Stryker Capabilities Development Document (CDD) was expected to receive JROC approval in 2009 (Fahey, 2008, slide 42). The CDD identifies operational performance attributes of the proposed system or increment KPPs; it is a required document for a program's Milestone B review (CJCS, 2007b, May, p. B-1).

Originally, the Stryker's user proponent, the Training and Doctrine Command (TRADOC) System Manager (TSM), was located at Fort Monroe, Virginia, and it served as the coordinating organization for the Stryker's requirements. In 2002, the Army transferred the user proponent to Fort Benning, Georgia (the home of the Army's Infantry Center), and it became known as TSM SBCT. In 2007, the Army re-designated TSM SBCT as a TRADOC Capability Manager (TCM), and it was renamed TCM SBCT. Each of the Army's branch proponents provides input to TCM SBCT on the Stryker's Mission Equipment Packages (MEPs). The Armor Center, located at Fort Knox, Kentucky, provided input for the MGS MEP.

2. The Role of the MGS within the SBCT

The MGS provides a medium-infantry support capability to the SBCT Combined Arms Company, and it complements the nine other Stryker variants. The ORD describes the critical nature of the MGS:

> The MGS is essential in setting and maintaining the tactical conditions for this collective overmatch by providing the capability to rapidly and in succession engage and destroy a diversity of stationary and mobile threat personnel, infrastructure, and materiel targets. It will have the capability to apply a broad

spectrum of munitions with lethal effects under all weather and visibility conditions. (Federation of American Scientists, 2000)

The MGS Annex of the ORD states that the "principal function of the MGS is to provide rapid and lethal direct fires to support assaulting infantry" (Federation of American Scientists, 2000).

3. Firepower

The primary requirement of the MGS is to provide the infantry with supporting fires (also a KPP), particularly with destroying enemy bunkers and sniper positions. With its 105mm main gun, the MGS is required to defeat a threat infantry squad at a minimum distance of 50 meters and at a maximum distance of 500 meters. The MGS also has to deliver this lethal fire with precision against fighting positions in buildings and light structures. Although it was required to destroy a variety of vehicles ranging from light-skin trucks to T-62 tanks, the ORD stipulated this be for self-defense only. The main gun can depress to -5 degrees, elevate to +15 degrees over the front of the vehicle, and +9 degrees over the rear of the vehicle (Federation of American Scientists, 2000). The turret and main gun is powered with an electric drive system similar to that of the Bradley Fighting Vehicle, with both stabilized and non-stabilized modes as well as a manual back-up (Federation of American Scientists, 2000).

The MGS has an M-240C 7.62mm coaxially mounted machine gun on the left side of the main gun that can accurately engage threat troops at a maximum effective range of 900 meters. The M-240C elevates and depresses with the main gun and, therefore, has the same elevation and depression requirements as the main gun. Both the commander and gunner control the main gun and coaxially mounted machine gun. The MGS also stores 18 main gun rounds, with all 18 in a ready configuration (Gary Gerlach, Project Engineer, PEO GCS, personal communication, January 20, 2009).

The fire control system supporting the main gun and coaxial machine gun provides day and night engagement capability in all types of weather. The Compact Modular Sight (CMS) provides a forward-looking infrared sight (FLIR), eye-safe laser range finder (ELRF), and direct view optics (Gary Gerlach, Project Engineer, PEO GCS, personal communication, January 20, 2009).

4. Survivability

The crew of the MGS has the same level of protection and survivability as the ICV variants. The base armor of the Stryker is required to provide 360-degree protection against 7.62mm fire and 14.5mm protection with additional armor protection.

The initial requirements for the MGS did not stipulate the use of armor protection for the main gun or coaxial machine, although it did require full protection for the crew inside of the turret. To protect the three-man crew from a secondary explosion of the main gun's ammunition, the MGS stores the main gun ammunition separately from the crew (TRADOC, 2008, p. 19).

5. C4ISR

The C4ISR requirements on the MGS are similar to those on the ICV variants. As part of the SBCT, the MGS can rapidly share, understand, and network information to achieve a common operating picture (TRADOC, 2008, p. 6). The networking capability of the Stryker allows the SBCT to span a larger area than Legacy formations and to respond in a rapid manner to changes in the operating environment.

The networking capability is particularly important to the MGS. The ability of the MGS to receive information from other Stryker platforms and infantrymen allows it to provide long-range, precision firepower. The MGS also has the same level of interoperability with current C4ISR suites as the ICV variants. The C4ISR system consists of the following:

- Intercom System,
- Radio System,
- Force XXI Battle Command, Brigade and Below (FBCB2) System,
- Ethernet Hub,
- Ground Positioning System,
- Driver's Vision Enhancer (DVE),
- Training Aids Devices Simulators and Simulations (TADSS), and
- Embedded Training Computer (ETC). (GDLS, 2002, p. 14)

The radio system consists of two Single Channel Ground Air Radio Systems (SINCGARS) radios (long-range and short-range) and an EPLRS radio. The FBCB2 system communicates through the EPLRS, and the GPS provides the FBCB2 with positional data (GDLS, 2002, p. 14).

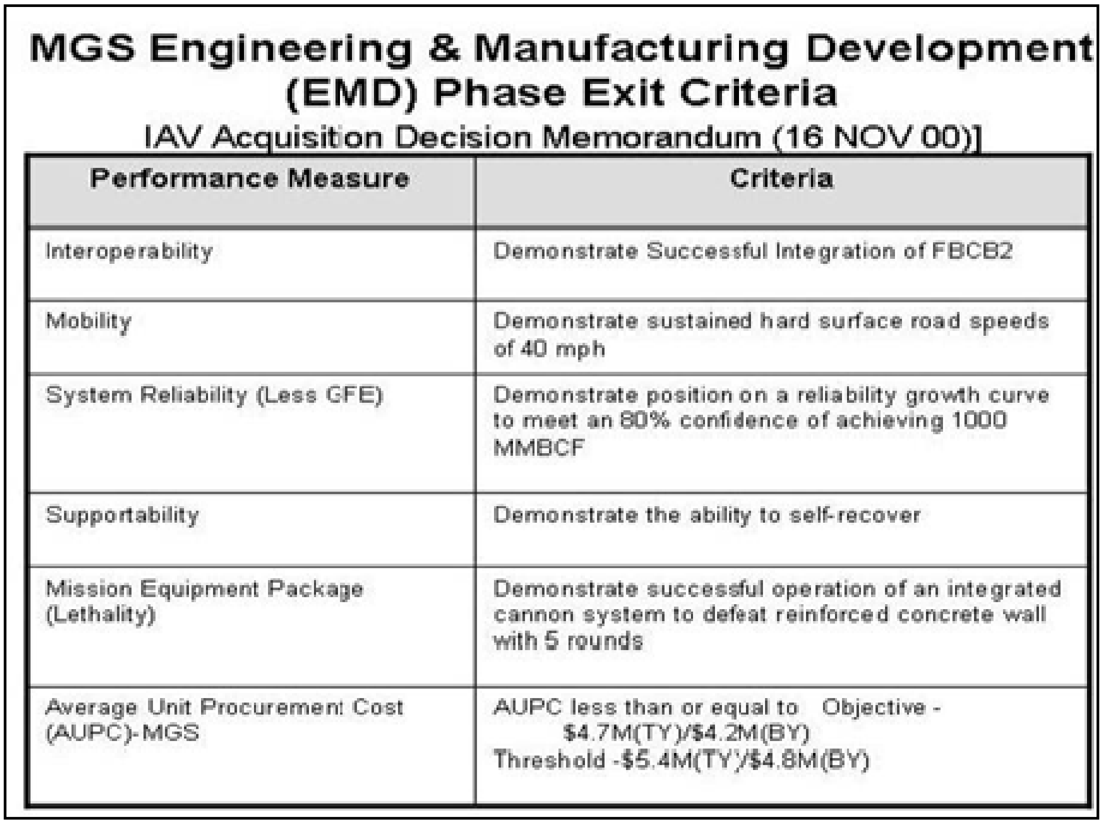
D. MGS Development

As of June 2009, the MGS was nearing the end of its developmental period. For the purpose of this case study, one can view its development in four overlapping stages. Chronologically, these stages are selection, protest and prototype development (2000–2002), early testing (2003), reliability growth (2004–2006), and deployment and the path to full-rate production (Fall 2006–2009). The focus of the case study is on the reliability growth period from 2004–2006; however, a clear understanding of the events leading up to this period is essential.

The early stages of the MGS followed a turbulent cycle of development until the MGS PMO instituted the use of systems engineering methodology to integrate all of the program's activities. Prior to the implementation of the systems engineering approach, the program experienced a turbulent development period. The Army deployed the MGS to Operation Iraqi Freedom in 2007, where it received positive feedback from soldiers (Censer, 2008, April 15).

1. Stage 1–Selection, Protest, and Prototype Development (2000–2002)

During the November 2000 Stryker Defense Acquisition Board (DAB) meeting, the Defense Acquisition Executive (DAE) required successful completion of six exit criteria for the MGS prior to its entrance into Low-rate Initial Production (LRIP) (PM SBCT, 2008, slide 34) (see Figure 7).


MGS Engineering & Manufacturing Development (EMD) Phase Exit Criteria

IAV Acquisition Decision Memorandum (16 NOV 00)]

Performance Measure	Criteria
Interoperability	Demonstrate Successful Integration of FBCB2
Mobility	Demonstrate sustained hard surface road speeds of 40 mph
System Reliability (Less GFE)	Demonstrate position on a reliability growth curve to meet an 80% confidence of achieving 1000 MMBCF
Supportability	Demonstrate the ability to self-recover
Mission Equipment Package (Lethality)	Demonstrate successful operation of an integrated cannon system to defeat reinforced concrete wall with 5 rounds
Average Unit Procurement Cost (AUPC)-MGS	AUPC less than or equal to Objective - $4.7M(TY)/$4.2M(BY) Threshold -$5.4M(TY)/$4.8M(BY)

Figure 7. EMD Exit Criteria
(PM SBCT, 2008, slide 34)

Soon after the start of work for the contract in April 2001, GDLS initiated the production of the eight preproduction MGS models. In July 2002, the MGS PMO believed that the program required 27 months of development prior to Low-rate Initial Production (LRIP) in June 2003 (Hsu, 2002, July 22). The initial LRIP was 2002, but the program manager moved it to 2003 based on the award protest.

The development of the eight preproduction models took place at the General Dynamics Muskegon Technology Center in Michigan. The Muskegon Technology Center provided GDLS with the capabilities needed to handcraft eight vehicles for Production Qualification Testing (PQT). In March 1996, GDLS purchased the Muskegon Technology Center from the Teledyne-Waterpik Corporation; the facility specialized in the development of handcrafted armored vehicle prototypes (LTC Shane Fullmer, personal communication, February 27, 2009). Additionally, Teledyne-Waterpik's Muskegon technology facility was the original designer of the Low Profile Turret (LPT) for the LAV III, and it had the engineering expertise to develop these vehicles for the Army (LTC Erik Webb, personal communication, December 5, 2008).

However, the processes of the Muskegon facility concentrated on handcrafted research and development activities, not on production (Kim McCormick, GDLS PM MGS, personal communication, January 22, 2009). The engineers at Muskegon had previously worked with the Aries auto-loader portion of the ammunition handling system, and, as a result, they were confident that they could successfully integrate the replenisher as well. The mindset of the engineers at Muskegon was that they could accomplish anything given enough time (LTC Shane Fullmer, personal communication, February 27, 2009).

In July 2002, the Army received its first pre-production model, but PQT would not begin until November 2002. The MGS prototypes differed from the demonstration version used during the 2000 PPD in that they had:

- Increased armor protection,
- An integrated C4ISR suite,
- An integrated ten-round replenisher,
- A 7.62mm coaxial machine gun,
- A .50 caliber commander's machine gun,

- A commander's panoramic viewer integrated with the fire control system,
- An eight-round carousel as opposed to a nine-round version, and
- Fire control modification to integrate all main gun ammunition and coaxial machine guns. (Gourley, 2003, May)

The initial preproduction vehicles received in July 2002 did not contain the entire AHS. These vehicles had the auto-loader system but lacked the replenisher, which GDLS did not deliver until September. Even then, it took over a month to get the replenisher to line up a round to feed into the auto-loader system's carousel located in the Low Profile Turret (LTC Shane Fullmer, personal communication, February 27, 2009). Several individuals in the MGS PMO immediately realized that the Aries AHS design would present problems, but the extent of these problems was uncertain until the test community verified them during PQT (LTC Shane Fullmer, personal communication, February 27, 2009). The PM planned for the PQT to support a scheduled Low-rate Initial Production (LRIP) decision in June 2003. In late 2001, the Army planned to field the MGS to the first SBCT in 2005 (see Figure 8).

The first set of challenges that the MGS PMO anticipated was the vehicle's weight. To meet the C-130 Transportability KPP, the MGS's PQT weight limit was 40,592 pounds, and the initial prototypes were approximately 43,865 pounds. Although the MGS was overweight by 5,000 pounds, the Army continued with the June 2003 LRIP decision because it had a two-stage weight reduction program in place to ensure the MGS met the C-130 KPP (Winograd, 2002, November 25).

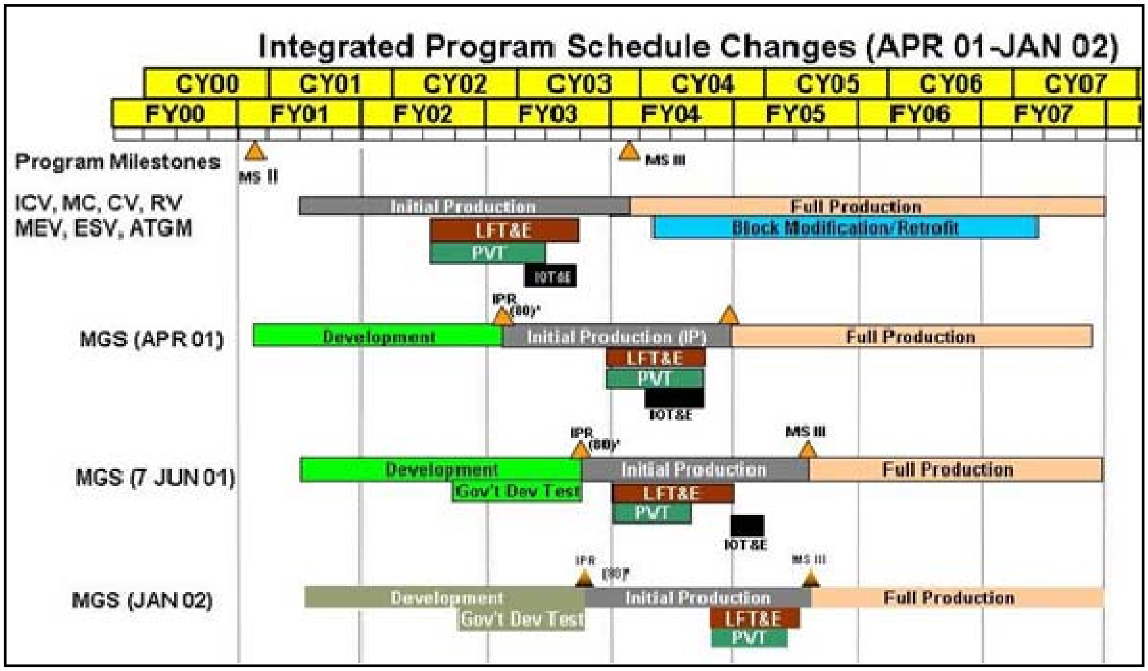


Figure 8. MGS Program Schedule Adjustments April 2001–January 2002
(PM SBCT, 2008, slide 45)

2. Stage 2–Early Testing (2003)

The Army began its PQT at Aberdeen Proving Ground in February 2003. Soon after PQT began, the Army was disappointed with the mounting problems found in the MGS prototypes. The intent of the PQT was to provide system-level testing to determine the stability of the design and its readiness for production. This meant that the failure modes should have been known and consistent; however, new failure modes were frequently appearing (LTC Erik Webb, personal communication, March 10, 2009). This indicated that the design was unstable and that it needed sub-component testing. First, the MGS showed 50 problems with human systems integration, known as Manpower and Personnel Integration (MANPRINT), and it had to reconfigure much of the C4ISR components to allow soldiers to fit and function inside the vehicle. Second, the Army noticed a problem with the ammunition handling system (AHS). The AHS had difficulty reloading ammunition because of the alignment between the replenisher and the carousel (Baumgardner, 2003, May 23). Third, after lowering the 105mm turret five inches to meet the C-130

Transportability KPP, the blast overpressure from the main gun muzzle brake was causing a halo effect on the front of the vehicle, damaging components mounted to the external hull (Joseph Godell, Deputy PM MGS, personal communication, March 6, 2009).

The engineering effort involved in lowering the turret caused the Army to suspend PQT for two months (Joseph Godell, Deputy PM MGS, personal communication, January 6, 2009). GDLS determined that the recoil mechanism could absorb the additional recoil without any redesign, beyond the elimination of the muzzle brake (Joseph Godell, Deputy PM MGS, personal communication, January 8, 2009). The PQT began again in July 2003, and the Army completed it in November 2003. These engineering issues led to the rescheduling of LRIP to February 2004 and then to September 2004.

Despite the problems encountered during PQT, the Army was satisfied with the GDLS fixes to the MANPRINT problems, main gun overpressure and recoil, and the AHS. The Army then proceeded to the LRIP decision in September 2004. To meet the criteria for LRIP, the MGS had to meet all of its Key Performance Parameters (KPPs) to include the C-130 KPP, the vehicle cost objective, and a requirement to achieve 1,000 mean miles between system abort (half of the requirement of the ICV) (Roosevelt, 2004, August 11). The Army defined system abort as any type of significant system failure that occurred on the vehicle. Of the six exit criteria, the system abort requirement was the most ambiguous because it did not clearly define the minimal reliability requirement for the auto-loader system.

The Defense Acquisition Executive (DAE), Michael Wynne, chaired the Defense Acquisition Board (DAB) meeting that determined the LRIP decision. The DAB made a determination based on the analysis of the test results from the Director of Operational Testing & Evaluation (DOT&E) and the Army Test and Evaluation Command (ATEC). The analysis stated that the MGS met the requirements for operational effectiveness, but fell short of meeting the minimum criteria for operational suitability, mainly because of the MEP reliability (Wynne, 2004, p. 1). At the DAB meeting, Wynne expressed substantial concern over the reliability of the MGS, but he still approved the limited LRIP of 14 vehicles with several caveats. His doubts centered on the ammunition handling system, and he required the Army to update the Stryker Systems Engineering Plan (SEP) within 90 days (Joseph Godell, Deputy PM MGS, personal communication, January 6, 2009). It was at this point that the Army began to adjust its expectations for the MGS. Rewriting the SEP would entail a complete review of the design and the approach towards improving reliability.

After the September 2004 DAB meeting, the MGS PMO became acutely aware that the development of the MGS would require even more time than was expected—as well as additional patience (DiMascio, 2004, October 11). As the schedule of the MGS continued to slip, elements of the user community compounded the technical problems caused by the auto-loader's reliability when they changed the requirements for the armor protection of the MGS (DiMascio, 2004, October 11).

3. Stage 3–Reliability Growth (2004–2005)

While the ICV chassis that the MGS used was highly reliable, the low inherent reliability of the Mission Equipment Package (MEP) reduced the overall reliability of the MGS. Failure data collected during PQT pointed towards the three components that made up the AHS as the major cause for poor MEP reliability and, in particular, the AHS replenisher (Joseph Godell, Deputy PM MGS, personal communication, January 6, 2009).

The difference between the actual reliability of less than 20 rounds per Operational Mission Scenario/Mission Profile (OMS/MP) cycle and the required reliability of at least 90 rounds per mission cycle without a failure was significant, and this required tremendous persistence and innovation to remedy (LTC Erik Webb, personal communication, May 20, 2009). Both the Army and GDLS knew that drastic measures were necessary to increase the overall reliability of the

MEP, and this required a costly and extensive reengineering effort that led to a change in the schedule (see Figure 9).

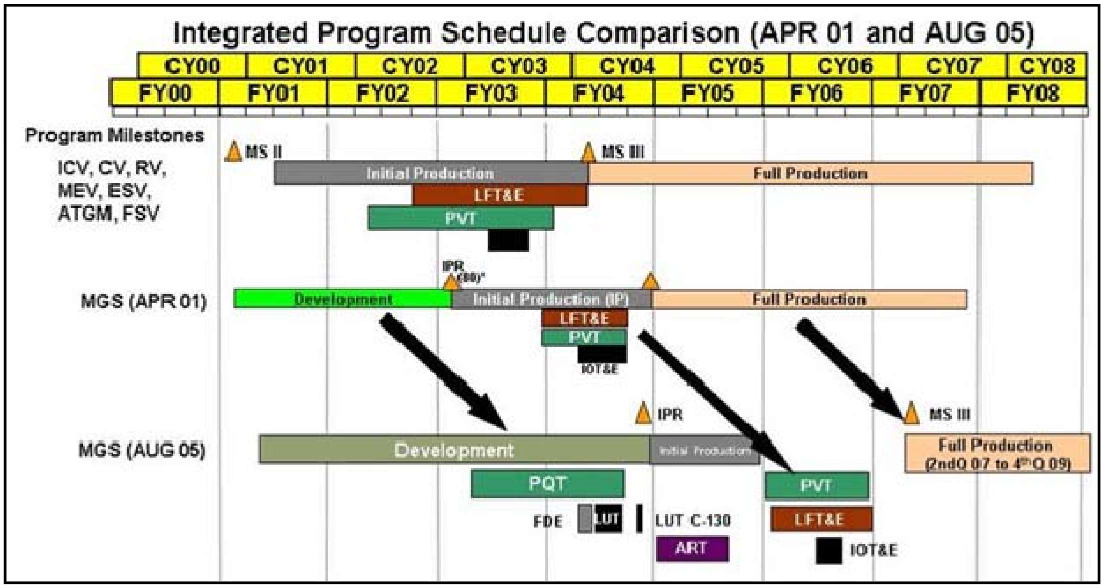


Figure 9. Stryker MGS Program Comparison Schedule
(April 2001 and August 2005)
(PM SBCT, 2008, slide 49)

The problems with the auto-loader caused GDLS to abandon its original auto-loader design, developed by Aries, and instead use a contractor-initiated source selection to choose a new sub-contractor, Western Design, which proposed a more reliable design (Joseph Godell, Deputy PM MGS, personal communication, January 6, 2009). The MGS PMO employed a Reliability Growth Analysis (RGA) methodology based on systems engineering to provide the program leadership with the information needed to make decisions on resourcing and scheduling (Chang & Rohall, 2008, September, p. 267). The MGS PMO encountered the problem of testing for numerical reliability targets midway through development, when reliable systems are often the result of the early use of systems engineering fundamentals (Defense Science Board, 2008, May, p. 5). The use of systems engineering uncovers problems at an early stage, when the program can incrementally correct them. The case study explores this topic in more detail in Chapter V.

While the reliability issues were occurring, the Army's user community and the Director of Operational Testing and Evaluation (DOT&E), under the Office of the Secretary of Defense (OSD), made the determination that the MGS PMO needed to increase the gun pod's armor protection based on modeling and simulation of future tactical scenarios. The additional capabilities requested by the user community and the OSD required additions to the updated MGS TEMP, as well as further reengineering effort. The increase in armor protection required trade-offs in capabilities to ensure that the MGS met the C-130 KPP. The MGS PMO now faced the issue of improving the MGS reliability and gun pod survivability while concurrently maintaining an acceptable system weight (DiMascio, 2005, January 24).

The new auto-loader contractor, Western Design, replaced the replenisher to reduce the complexity of the auto-loading and replenishing mechanisms. The Aries replenisher had consisted of two five-round drums, whereas the Western Design replenisher consisted of one ten-round drum. After several months of intensive RGA effort as part of the test program, the reliability of the system was approaching the necessary parameters. Consequently, the new DAE, Ken Krieg, approved the final LRIP of 58 vehicles in October 2005 after reviewing the new operational suitability test results (DiMascio, 2005, November 14). Although reliability growth was not the final development hurdle for the MGS, it opened the way for the LRIP decision.

The use of the RGA and systems engineering process provided the MGS Program Office with an objective means of understanding what was occurring with the MGS during testing. By 2006, the MGS was exceeding its reliability targets.

4. Stage 4–Deployment and the Path to Full-rate Production (2006–2008)

After production approval for the remaining 58 LRIP vehicles, the MGS Program conducted additional Production Verification Testing (PVT), beginning in February 2006. The purpose of the PVT was to provide information to support the

Milestone III decision for Full-rate Production (FRP), scheduled for 2007 (DiMascio, 2005, December 12). To meet the Milestone III requirements, the MGS also had to undergo Live Fire Test and Evaluation (LFT&E) and an Initial Operational Test (IOT).

Although the Army had a Full-rate Production decision scheduled for 2007, the Iraq Surge diverted the Fort Lewis-based test unit, the 4th Stryker Brigade Combat Team of the 2nd Infantry Division, a unit that the Army had previously scheduled to support the MGS IOT. The Army subsequently rescheduled the Full-rate Production decision for February 2008 after it designated another SBCT as the IOT support unit (Joseph Godell, Deputy PM MGS, personal communication, January 6, 2009).

While the MGS still required LFT&E and operational testing, the Chief of Staff of the Army, General Peter Schoomaker, determined that the MGS was capable of operational deployment with the 4th SBCT/2nd ID to Iraq. He based this decision on the recommendation from the December 2006 Army System Acquisition Review Council (ASARC) (Joseph Godell, Deputy PM MGS, personal communication, January 8, 2009). Although the Army acknowledged that the MGS required "fixes" during its deployment, the vehicle successfully performed its mission in theater (Joseph Godell, Deputy PM MGS, personal communication, January 8, 2009).

To resolve these concerns, the MGS PMO and GDLS implemented accuracy improvements to the coaxial machine gun, reliability fixes to the electronic power components, a better cooling system for the vehicle's three-man crew, and software improvements to the commander's display unit (Censer, 2008, May 19). To address these issues, the MGS PMO developed a near-, mid- and far-term plan to implement the fixes recommended by the DOT&E to allow FRP of the MGS. The Army then conducted a Configuration Steering Board (CSB) in October 2008 to review the product manager's mitigation plan and the impacts of implementing the changes on cost and schedule (Roosevelt, 2008, August 22, p. 1). The recommended fixes included both requirements shortfalls from the base MGS requirement document, observations from the use of the MGS in theater, and DOT&E observations from testing that were not traceable to an approved requirements document (COL Robert Schumitz, PM SBCT, personal communication, January 29, 2009).

E. Conclusion

While the MGS program offers a useful case study for lessons learned, the developmental challenges encountered were not idiosyncratic to this program. The Army has encountered similar problems with complexity in other acquisition programs. In fact, a GAO report on the SGT York, an air defense weapon system developed in the early 1980s, revealed this:

> One reason for the delay in fielding the (system) was that the prototype gun systems the contractors delivered for testing were less technically mature than anticipated. This caused testing delays and the need for more testing than had been planned. The integration of the weapon's major subsystems and their application to a weapon for which they had not been originally designed apparently represented a greater technical undertaking than originally anticipated. (Conahan, 1986, pp. 4-5)

Outside of the MGS program, there was tremendous support for the MGS. General Peter Schoomaker, the Army's Chief of Staff after General Shinseki, was a "stalwart supporter" of the MGS (DiMascio, 2005, January 24). This chapter provided a broad overview of what capability the Army needed from the MGS, as well as a chronological progression of how it evolved from 2000 to 2008.

The focus of Chapter V is on the MGS development from 2000–2005, with an emphasis on how the MGS program adapted to the complexity of the outer environment by analyzing the system's integration of the ammunition handling system.

V. Managing Complexity

A. Introduction

A program's developmental trajectory is seldom smooth, and it typically involves overcoming unanticipated challenges. Chapter IV provided a brief description of some of the developmental challenges that the MGS encountered. In many ways, everything was harder than expected for the MGS, particularly with systems integration (COL Robert Schumitz, PM SBCT, personal communication, November 25, 2008). The initial momentum of the program and the commitment to success by the program's leadership overcame some of these challenges, but the MGS required a change in approach to make it through the crisis period of 2004-2005. The crisis occurred because of an inability to meet reliability objectives for LRIP, but the root cause of the crisis was an approach that did not adequately address the complex environment. To meet the demands of the complex environment, the MGS PMO self-organized around a systems approach that identified and managed risk.

The primary area of risk for the program during this period was the low level of reliability for the MGS ammunition handling system (AHS). This chapter provides an overview of the AHS, the problems experienced with the AHS, the systems engineering approach adopted by the MGS PMO and GDLS, and then closes with an analysis of the program's adaptation to the complex environment.

B. The Ammunition Handling System

1. Aries Design

Early on, GDLS sub-contracted with the Aries Company for a previously developed AHS under a fixed-price contract (LTC Shane Fullmer, personal communication, February 27, 2009). Aries had an off-the-shelf auto-loader available, but it required the development of a replenisher system for the MGS. For the MGS, the AHS consisted of three components: 1) a carousel, 2) a rammer, and 3) a replenisher (see Figure 10).

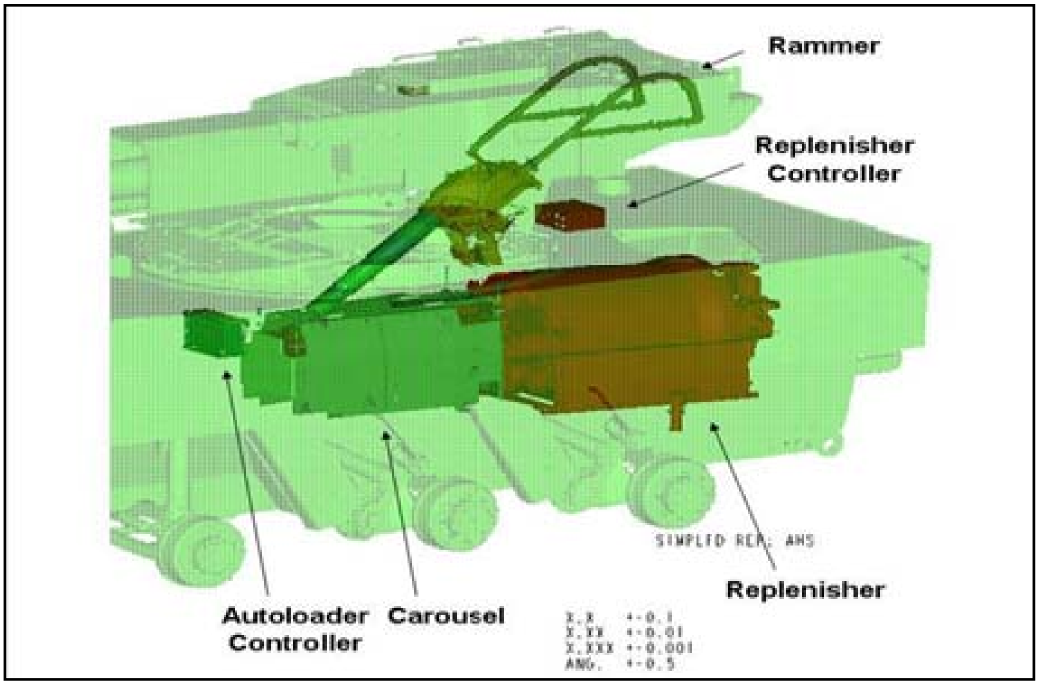


Figure 10. The Ammunition Handling System
(GDLS, 2005c, slide 3)

The Aries design used pneumatic power, and it had eight rounds in the carousel, with ten rounds in two separate 5-round drums. When commanded to load a round, the eight-round carousel raised the 12 o'clock position tube containing the desired round; the hydraulically actuated rammer picked up the round from the carousel and transferred it to the gun breach, where it was loaded (LTC Erik Webb, personal communication, May 20, 2009). To reload the carousel, rounds were pneumatically loaded into the carousel located in the Low Profile Turret (GDLS, 2005b, slide 3). There were early indications that the AHS was problematic. Soon after the delivery of the first pre-production vehicles in 2002, the Army noticed that the Aries AHS had difficulty with aligning rounds while transferring them from the replenisher to the auto-loader.

2. Reliability in Early PQT (2003)

The requirement for reliability at the start of the program was 1,000 Mean Miles Between System Abort (MMBSA) (Chang et al., 2009, March, p. 3). The MMBSA measure was based on the performance specifications within the RFP, which required the developer to state reliability in terms of "system abort failures" (Gamboa, 2001, April 9, p. 17). Furthermore, the RFP required offerors to "identify predicted or demonstrated system level reliability for each IAV variant or configuration and to discuss failure definition, data sources, and operating environment profile showing applicability to the IAVs" (Gamboa, 2001, April 9, p. 17). As part of the proposal package, the government required each of the offerors, GDLS in this case, to assess its own predicted reliability in view of the risks associated with integrating highly complex components. Considering the performance of the AHS during PQT, it appears that GDLS overestimated the reliability of the AHS.

In 2003, the Army conducted Reliability, Availability, and Maintainability (RAM) testing as part of PQT at the Aberdeen Proving Grounds. During this testing, the Army required the vehicles to drive 8,000 miles and fire 640 rounds with the goal of achieving an 80% confidence level that the production system could achieve 1,000 MMBSA (Baumgardner, 2003, July 10, p. 1). The AHS failed to achieve the required system-level reliability, and the Army terminated PQT approximately two-thirds of the way through the test (Chang et al., 2008, September, p. 269).

The MGS PMO relied on a "test-in" approach for reliability because there was not a Design for Reliability (DFR) requirement in the original contract, and the compressed timeline made it nearly impossible for GDLS to conduct DFR during EMD (N. Jenny Chang, Tank & Automotive Command Reliability Engineer, personal communication, March 4, 2009). During PQT, the MGS PMO used a closed-loop Failure Reporting and Corrective Action System (FRACAS) that did not provide an efficient means for reliability growth because of a slow reaction time in identifying where failures were occurring in the system. One of the consequences of the slow reaction time was that reliability at the end of the PQT was essentially the same as the reliability at the beginning (N. Jenny Chang, Tank & Automotive Command Reliability Engineer, personal communication, March 4, 2009).

Based on these results, a September 2004 Defense Acquisition Board (DAB) review required the MGS PMO to improve the reliability of the system prior to moving to LRIP. Under the post-DAB testing plan, the DAE required that the MGS undergo further RAM tests in FY04 and 1Q/FY05. These RAM tests included driving 12,000 miles and firing 1,000 rounds, with the objective of achieving the 1,000 MMBSA (DiMascio, 2004, September 13). One outcome of the September 2004 DAB was that the MGS PMO and GDLS separated the reliability criterion for the MGS MEP from that of the chassis. The measurement criterion for reliability originates from two contractual documents created by the user: the Operational Mode Summary and Mission Profile (OMS/MP) and the Failure Definition and Scoring Criteria (FD/SC) (Chang et al., 2009, March, p. 154).

The OMS/MP is an appendix to the system requirements documentation. The purpose of the OMS/MP is to support the development of specifications and test plans by describing how a system will operate in different types of scenarios (DAU, 2009a). The FD/SC is a jointly developed document between the user and the materiel developer that defines system failure definitions during reliability testing (DAU, 2009b). Within the Stryker OMS/MP, the MGS performed two functions: accumulating miles and firing ammunition. However, the reliability criteria was changed because the MGS chassis was the same as the ICV variant—which already passed its reliability tests—and the cause of the MGS reliability shortfalls centered on the AHS (Chang et al., 2009, March, 154).

The result of this change was that MGS PMO kept the requirement for the MMBSA at 1,000 miles, and that it re-designated the new MEP reliability as Mean Rounds Between System Abort (MRBSA)—with a threshold performance of 81 MRBSA and an objective performance of 148 MRBSA (Chang et al., 2009, March, p. 154). Soon thereafter, the MGS PMO directed GDLS to abandon the Aries design and to find a new design for the AHS, as well as a new approach to improving the system reliability.

C. Reliability as a Design Consideration during the Systems Engineering Process

As a requirement, system reliability is an important design consideration throughout the systems engineering process, and it plays a critical role in a system's lifecycle. According to Blanchard and Fabrycky,

> Every system is developed in response to a customer need to fulfill some anticipated function. The effectiveness with which the system fulfills this function is the ultimate measure of its utility and value to the customer […]. [S]ystem effectiveness is a composite of many factors with reliability being a major contributor. (2006, p. 285)

After conducting a functional analysis, the developer constructs a reliability block diagram that allocates reliability from a top-down approach. The allocation of reliability also serves as an input for Failure Mode Effect and Criticality Analysis (FMECA) (Blanchard & Fabrycky, 2006, p. 385). Through the application of a systems engineering approach, the materiel developer designs for reliability (DFR), as opposed to testing for reliability (TFR) as an afterthought. Although the DFR approach requires sophisticated methodology, it is more cost-effective than the TFR approach. As a critical element of a system's overall performance, the developer addresses reliability in all stages of the systems engineering lifecycle model (see Figure 11).

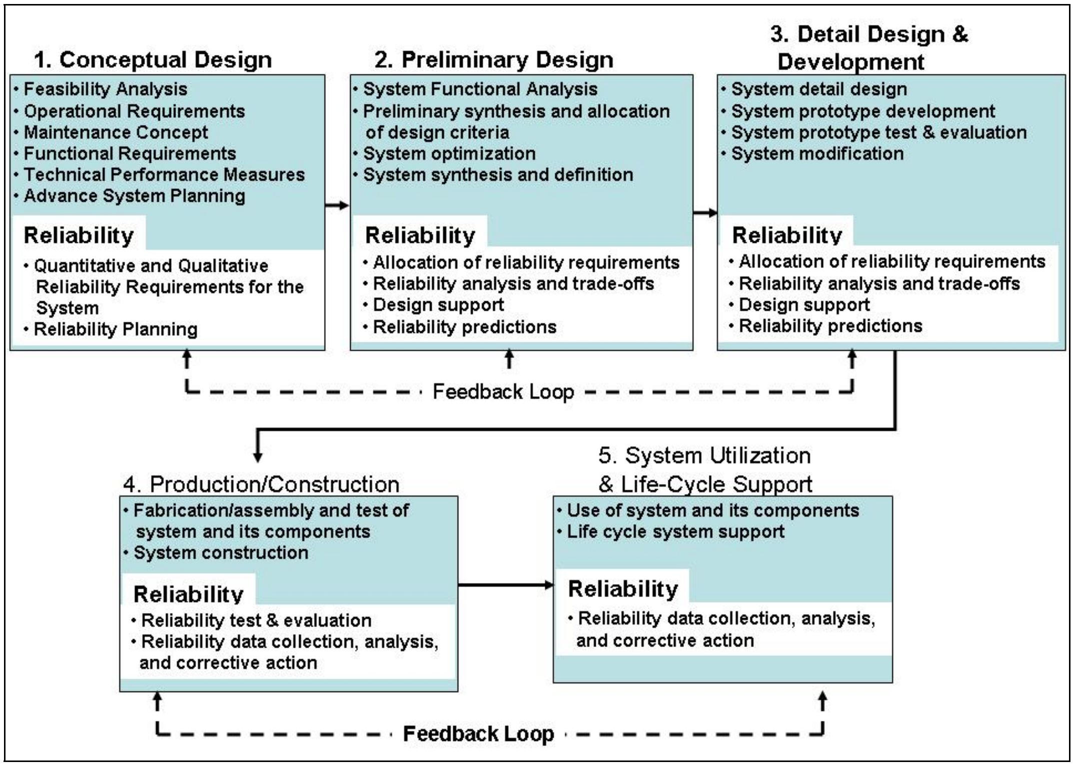


Figure 11. Systems Engineering Lifecycle Model with Reliability Embedded
(Blanchard & Fabrycky, 2006, p. 383)

According to the Army Materiel Systems Analysis Activity (AMSAA) *Reliability Growth Guide*, the consideration of reliability "is part of the systems engineering process," and systems engineering is merely a means of "viewing reliability program activities in an integrated manner" (2000, September, p. 4). The different reliability activities include design predictions, apportionment, failure modes and effects analysis, and stress analysis (2000, September, p. 4).

In short, reliability growth is a proven method to reduce failures by testing an item until failure modes or events occur, identifying the failures, and then fixing them. Reliability growth is an iterative design process, with five essential elements that include: 1) detection of failure sources, 2) feedback of problems identified, 3) redesign effort based on problems identified, 4) fabrication of hardware, and 5) verification of redesign effort (see Figure 12). The rate of reliability growth hinges on the speed at which these activities occur, the significance of the problems, and the effectiveness of the redesign effort, with any of these activities acting as a "bottleneck" to the overall reliability of the system (AMSAA, 2000, September, pp. 5-6).

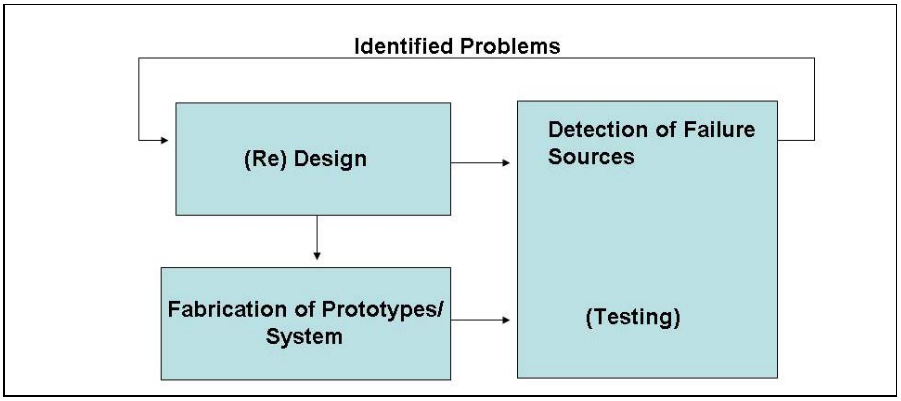


Figure 12. Reliability Growth Feedback Model with Hardware
(AMSAA, 2000, September, p. 5)

The key element to achieving a sufficient rate of growth is through improvements to a system's inherent reliability (Chang et al., 2008, September, p. 270). Inherent reliability is the element of reliability that materiel developers have control over, and it refers to the designed reliability of the system while operating under realistic operating conditions. The objective of materiel developers is to increase a system's inherent reliability during the design phase and to minimize unforeseen problems during system testing. In the case of MGS, the Muskegon Technology Center handcrafted the components together, but there was not enough time for contractor systems integration testing. In effect, the first two years of the MGS development consisted of trial-and-error tests for reliability.

D. Program Actions

Based on the failure to pass reliability standards during PQT, the MGS PMO initiated a reliability growth plan. After receiving the guidance of the September 2004 DAB, the MGS PMO developed a new path forward that included a phased plan to address the reliability issues (see Figure 13):

- Phase I: Additional Reliability Testing (ART),
- Phase II: Systems Engineering Revitalization, Management and Process Improvements, and
- Phase III: Redesign of the Ammunition Handling System. (PM SBCT, 2006, p. 59)

The MGS PMO also developed a Phase IV plan that emphasized survivability improvements to the Low Profile Turret; however, that topic is beyond the scope of this case study.

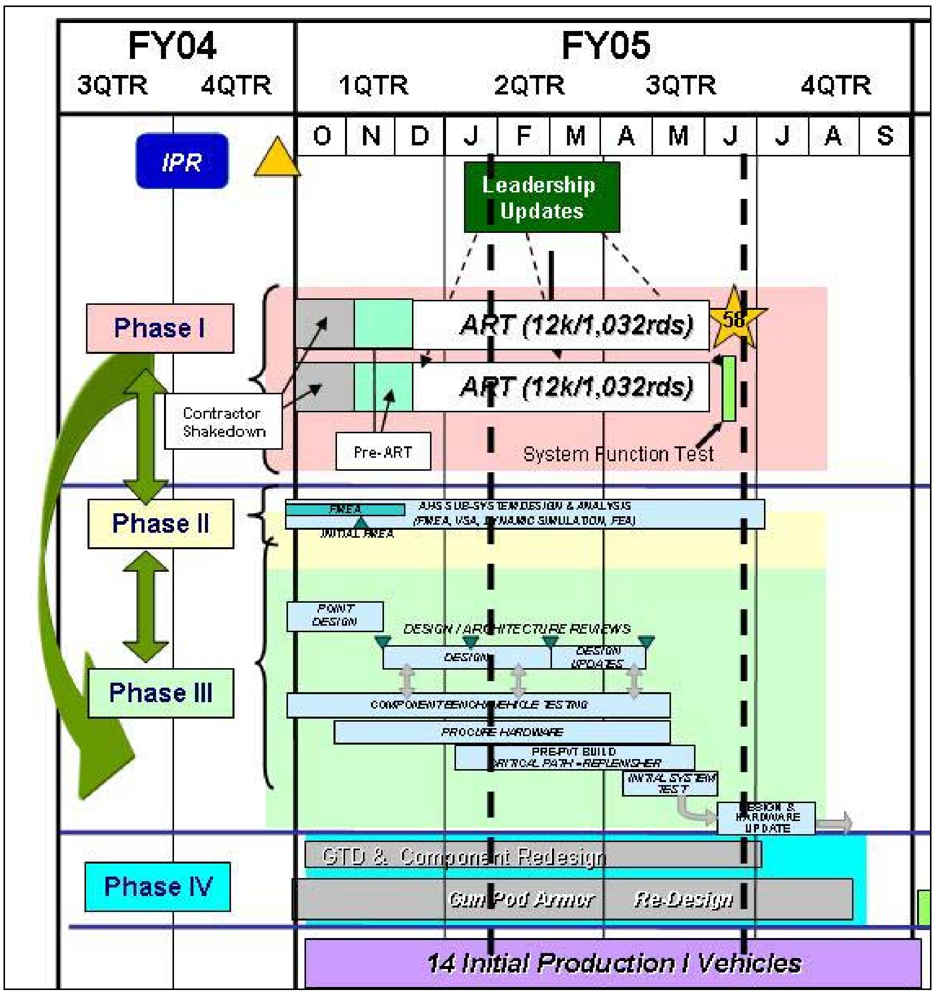


Figure 13. Schedule for Phase I-III
(Fuller, 2004a, slide 21)

1. Phase I: Additional Reliability Testing (ART)

Phase I served as a time to regroup and establish a new baseline for the program. Prior to ART, GDLS conducted a “contractor shakedown” to ensure that the MGS was “mature enough” for the Government’s ART (PM SBCT, 2006, p. 59). The overall purpose of Phase I was to demonstrate improvements to reliability since the conclusion of PQT and to validate the expectations of reliability growth. Phase I, ART, consisted of two elements, pre-ART and ART. The MGS PMO and GDLS conducted pre-ART from November 8-18, 2004, and ART from December 2004 to June 2005. ART allowed the MGS PMO and GDLS to develop and validate the corrective actions for the system-abort modes that evaluators identified during the 2003-2004 PQT.

Phase I also reestablished the MGS baseline, and this served as a starting point for the next stage of testing. The actions taken during Phase I also allowed the MGS PMO to review and validate the new reliability growth plan developed by GDLS (Fuller, 2004a, November 17, slide 5). The MGS PMO conditionally accepted the GDLS reliability growth plan, which called for monthly updates to MGS stakeholders (2004a, November 17, slide 5). While ART occurred, GDLS conducted a parallel effort to select and conduct component-level testing on a new design for the AHS.

2. Phase II: Systems Engineering Revitalization, Management and Process Improvements

The centerpiece of Phase II was the use of a systems approach to organize the program’s available knowledge and tools. Pragmatically, the MGS PMO and GDLS implemented the systems approach through a “revitalized” systems engineering plan (PM SBCT, 2006, p. 59). During Phase II, the MGS PMO and GDLS prepared the systems engineering plan for OSD approval in January 2005 (Fuller, 2004a, November 17, slide 6). GDLS also dedicated a new team of systems engineers to the MGS program for implementation of the plan.

The new systems engineering plan not only addressed the redesign of the AHS, but it also addressed the managerial processes that governed daily activities within the program (Chang et al., 2009, March, p. 152). Within GDLS, all of the employees assigned to work on the MGS were required to complete a course on Whole Systems Architecture and Design Failure Mode and Effects Analysis training (Josh King, GDLS Stryker Project Engineer, personal communication, March 10, 2009). The training provided the employees, who came from a broad range of disciplines, with a common operating picture of how GDLS intended to approach reliability growth. The training also ensured that all of the project engineers understood how to prioritize failure modes in the design (Josh King, GDLS Stryker Project Engineer, personal communication, March 10, 2009). In a similar manner, PM SBCT established a 40-hour course on systems engineering, and this training was required for all key staff members (PM SBCT, 2006, p. 34).

a. MGS Integrated Product Teams (IPTs)

GDLS reassigned their Senior Director of Product Engineering to be the Senior Director of MGS Engineering. The Senior Director of MGS Engineering assumed central control over all MGS engineering decisions, and he reassigned a number of key employees to MGS full-time as Integrated Product Team (IPT) leads. The MGS PMO and GDLS required every IPT to have a technical manager and a lead systems engineer who had responsibility for "risk management, configuration management, technical data management, and to control physical and functional interfaces across subsystems" (PM SBCT, 2006, p. 42). GDLS assigned each of these IPT Leads to communicate with specific government organizations such as the user, materiel developer, and Army testers (Josh King, GDLS Project Engineer, personal communication, March 10, 2009). The Senior Director of MGS Engineering also institutionalized a multi-disciplinary IPT meeting structure to improve the flow of information (Josh King, GDLS Project Engineer, personal communication, March 10, 2009).

In a similar move, the government assigned personnel to each of the IPTs, and the MGS PMO reassigned one employee to GDLS on a full-time basis—allowing him to participate in daily meetings to enhance the collaboration between the government and GDLS (see Figure 14) (LTC Erik Webb, personal communication, March 10, 2009). PM SBCT assigned each IPT a charter that contained "pre-defined boundaries for decision-making," and the PM empowered all of the IPTs to make decisions at the lowest level possible (PM SBCT, 2006, p. 32). PM SBCT also established a set of weekly metrics to review issues, and it made this information available to everyone in the program by placing it into a common database known as the Integrated Data Environment (2006, p. 34). The MGS IPT metrics measured cost variance, schedule variance, and actual versus planned product definition release (2006, p. 35). Consequently, communications among functional areas and between the government and GDLS occurred on a more frequent and consistent basis, contributing to a collaborative "team atmosphere" (Josh King, GDLS Project Engineer, personal communication, March 10, 2009).

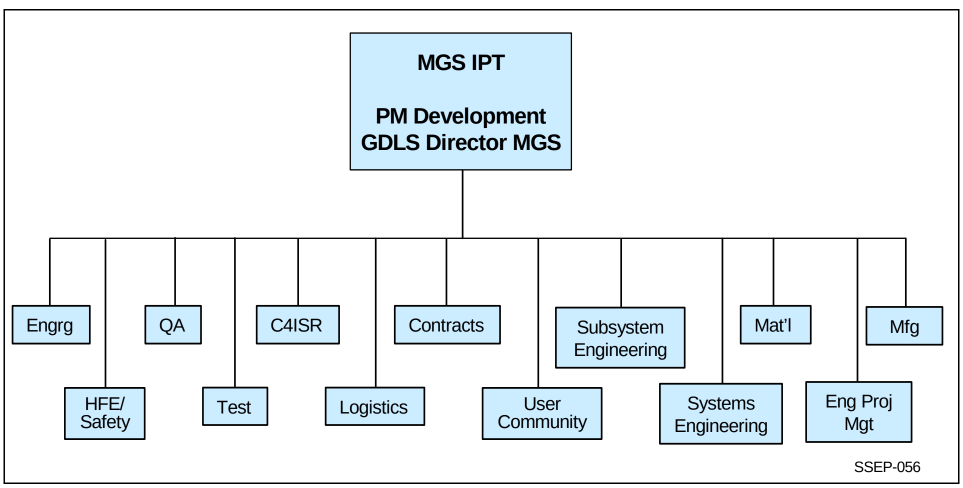


Figure 14. MGS IPT Structure
(PM SBCT, 2006, p. 31)

Specific to systems engineering, PM SBCT and GDLS instituted a joint Systems Engineering Integration Team (SEIT) with the purpose of coordinating all systems engineering activities (PM SBCT, 2006, p. 36). The SEIT had access to over 100 systems engineers, and it was “responsible for systems engineering technical management, including gate checkpoint reviews, problem management, and risk management” (PM SBCT, 2006, p. 36).

b. Failure Prevention and Review Board and the Design Actions and Reporting System

The MGS PMO and GDLS also instituted a multi-functional team to serve on a Failure Prevention and Review Board (FPRB) led by the MGS PMO. The FPRB met twice per week, and the MGS PMO used the FPRB to oversee the Design Actions Reporting and Tracking System (DART) and all corrective actions. The DART played a critical role in that it managed “the discovered failure modes as well as associated corrective actions” (Chang et al., 2009, March, p. 152).

The DART served as the primary reporting system for the Failure Mode Effects and Criticality Analysis (FMECA). With a relatively small sample size and a limited amount of time available for testing, the DART allowed for highly efficient identification and correction of failure modes (see Figure 15). The DART process was highly effective, and it reduced the cycle-time for corrective actions on failure analysis from 90 days to 45 days (Fuller, 2004b, December 20, slide 8).

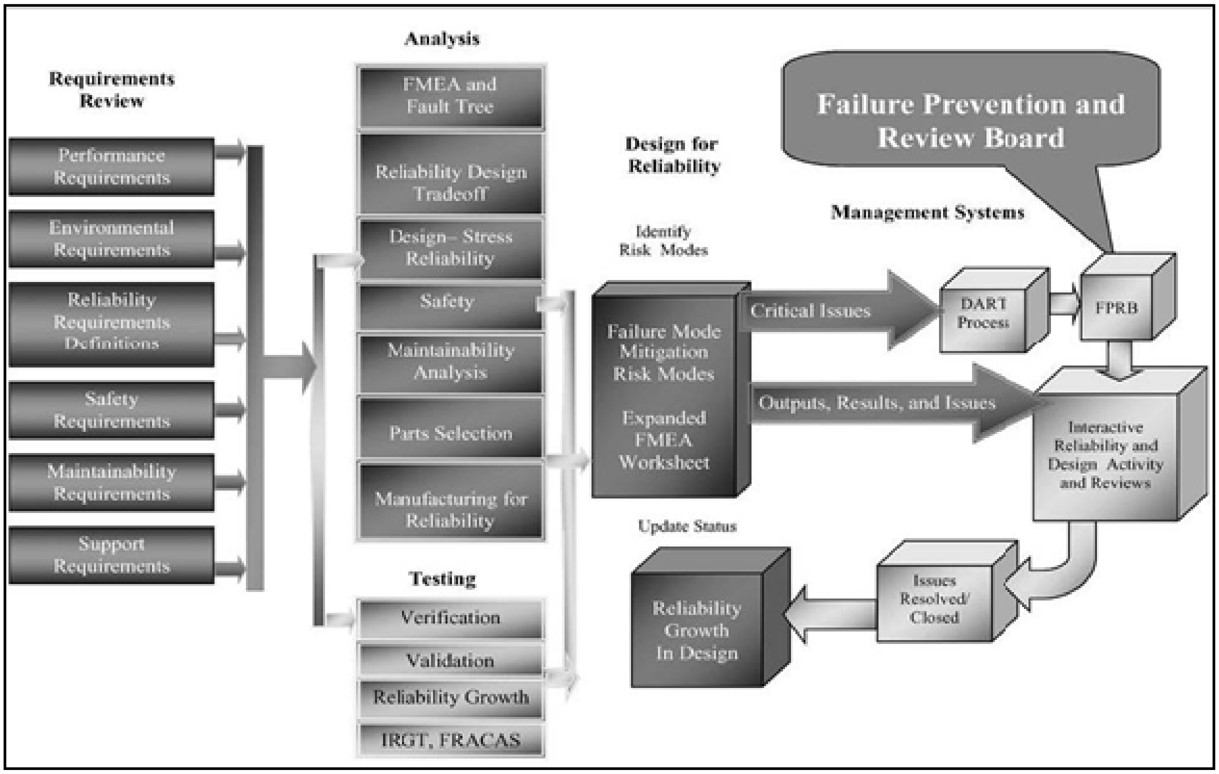


Figure 15. Design Actions Reporting and Tracking Process
(Chang et al., 2009, March, p. 153)

3. Phase III: Redesign of Major Subsystems and Integration

The purpose of Phase III was to "demonstrate reliability growth by conducting RGT" and to "redesign essential elements of the AHS" (PM SBCT, 2006, p. 60). On October 19, 2004, GDLS selected Western Design's AHS as the replacement for the Aries design. The new design had a 50% reduction in parts, and it replaced the two 5-round canisters with one 10-round canister in the carousel. In the second and third quarters of 2005, GDLS conducted systems integration of the Western Design AHS into the MGS (Fuller, 2004b, December 20, slide 12). During this period, GDLS conducted a Preliminary Design Review and a Critical Design Review as part of the reinvigorated systems engineering process for the new AHS as well as other design changes for the MGS (Fuller, 2004b, December 20, slide 13). Soon thereafter, GDLS conducted a short "contractor shakeout" test in June to August 2005, with government participation to determine the level of system reliability (Chang et al., 2008, September, p. 269). The actual reliability during contractor shakeout was 57 MRBSA, short of the threshold requirement of 81 (Kim McCormick, GDLS PM MGS, personal communication, January 22, 2009). The MGS PMO determined that the Production Verification Test (PVT) would need to serve as an additional reliability growth test (Kim McCormick, GDLS PM MGS, personal communication, January 22, 2009).

PVT began in May 2006 and finished in April 2008 with three production-like vehicles (Chang et al., 2009, March, p. 155). The actual reliability growth rate significantly exceeded the expected growth rate (38% versus 22%), demonstrating the effectiveness of the methodology developed in Phase I and II. The actual reliability during PVT was 104 MRBSA, which exceeded the threshold requirement (Kim McCormick, GDLS PM MGS, personal communication, January 22, 2009). When viewed in comparison to the 13 MRBSA in PQT, the improvement is substantial. It took the crisis of September 2004 to shift the MGS program from a series of incremental changes to a dramatic restructuring built around the systems approach.

E. Risk Management Process

The Stryker acquisition strategy attempted to minimize overall programmatic risk by using NDI and "near-NDI" (PM SBCT, 2006, p. 106). As part of the March 2000 acquisition strategy, the PM SBCT identified risk on a "top level in terms of program cost, schedule, and technical performance to allow informed decision-making" (PM SBCT, 2006, p. 106). After the revitalization of the systems engineering approach in 2004-2005, PM SBCT integrated risk into the systems engineering process with an effort to identify risk from the "bottom up" and from "top down perspectives" (PM SBCT, 2006, p. 106). PM SBCT and GDLS made use of the information derived from all collaborative groups to include the IPTs, the systems engineering risk team, and a risk review board in identifying risk and developing integrated solutions.

PM SBCT and GDLS initiated a process in which they formally discussed risk at all program reviews and program milestones. Additionally, PM SBCT and GDLS made all risk documentation available to stakeholders on the common IDE database (PM SBCT, 2006, p. 107). While PM SBCT was responsible for oversight of the risk management process, GDLS served as the primary manager for technical risk (PM SBCT, 2006, p. 106). PM SBCT and GDLS not only shared risk, but they also used a common risk management process that assessed risk on a continuous basis (see Figure 16). The next section examines the MGS from the perspective of complexity.

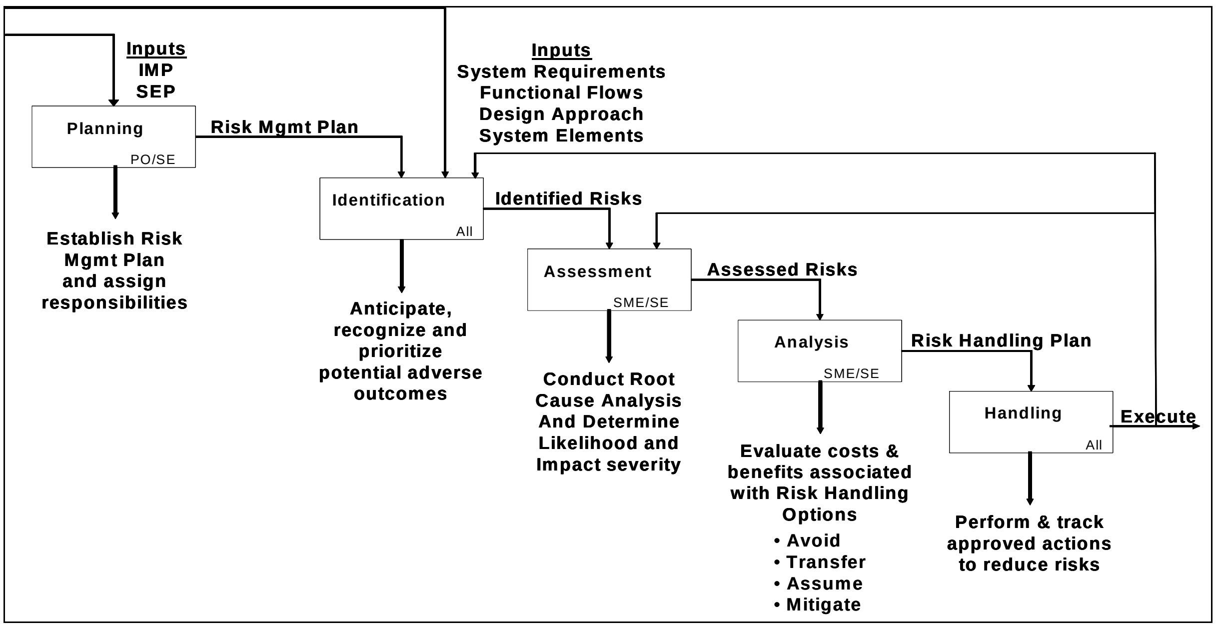


Figure 16. PM SBCT Risk Management Process
(PM SBCT, 2006, p. 106)

F. Complexity and the MGS

The literature review in Chapter II demonstrates that there are common properties to complex programs. What makes a program complex is not only the internal technical complexity of the system, but also the upstream complexity that originates from the outer environment. Based on this perspective, the MGS certainly qualifies as a complex program.

While the people who worked on the MGS program were extremely capable and dedicated to the program's success, the MGS still encountered numerous difficulties that resulted from organizational, environmental, and technical forces that affected the program. One way to explain the program is by describing it in terms of Simon's model of complexity described in Chapter II.

The complexity of the outer environment created uncertainty and, in the process, increased the MGS program's overall level of risk. The MGS program, representing the inner environment, was in a search to find an approach to manage the complexity and uncertainty that it faced. The next section addresses the outer and inner environments, and it provides an analysis of how the MGS PMO managed complexity.

1. The Outer Environment

According to Simon (1981) and Kauffman (1993), all complexity originates outside of a system, and, in the case of the MGS, the outer environment represents all factors that directly and indirectly had an impact on the MGS. Six risk factors stand out in this category, including: 1) the strategic uncertainty of the post-Cold War era, 2) time-based acquisition strategy, 3) the unintended consequences of the acquisition reforms of the 1990s, 4) the common developmental and non-developmental acquisition strategy, 5) the categorization of MGS as NDI, and 6) the focus on vehicle commonality (see Figure 17). These risk factors fall under one of three areas of criticality based upon information adequacy: 1) known-known, 2) unknown-known, and 3) unknown-unknown. All of these factors are interrelated, but the inexact and unknown causality of this relationship is what made the MGS program complex.

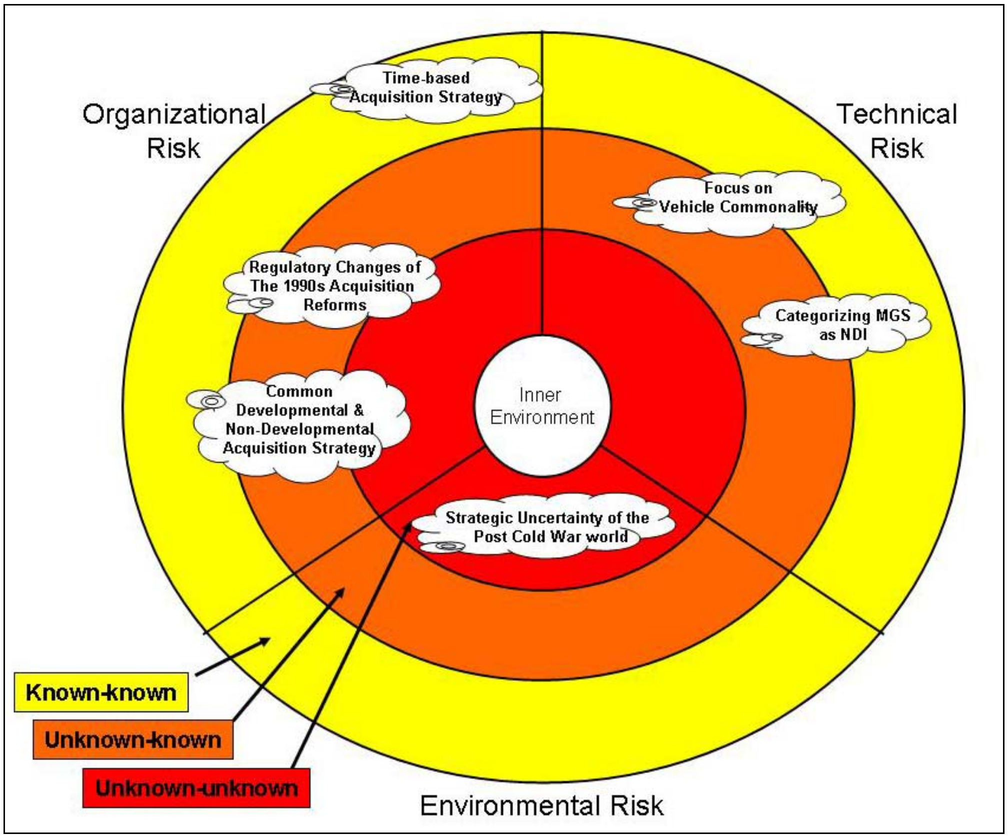


Figure 17. Simon's Complexity Model Applied to the MGS

a. Environmental Risk Factors

At the center of General Shinseki's ladder of inference was the uncertainty of the new multi-polar world. Unlike the bipolar world, the United States could no longer predict with any accuracy the actions of its adversaries. The post-Cold War period demonstrated that the United States required the flexibility of inserting a medium-size formation anywhere in the world within 96 hours, with the ability to address a continuum of operations ranging from humanitarian aid to major combat. The period from 1990-2008 demonstrated that this risk area was clearly positioned in the category of an unknown-unknown. Strategic uncertainty drove the Army's Transformation strategy and the time-based acquisition strategy.

b. Organizational Risk Factors

General Eric Shinseki, the champion of the Army's Transformation strategy, understood that this strategy was a long-term endeavor, and Stryker was merely the first increment of change. Beyond the technological challenges of transformation, he soberly determined that the single biggest obstacle to Army Transformation was the need to overcome the Army's own byzantine bureaucracy. As the decisive point of the Transformation strategy, he determined that Stryker required a time-based, rather than an event-based, strategy to achieve "irreversible momentum" (Shinseki, 2003). With a specific date for initial operational capability, this risk factor falls under the known-known category.

In retrospect, a two-year development period for a vehicle that required extensive systems integration may seem unreasonable; yet when viewed from the assumption that the MGS was close to ready and from the strategic perspective of General Shinseki, its rationale seems more apparent. The March 2000 *Acquisition Strategy Report for the Interim Armored Vehicle* served as the over-arching strategy for the developmental and non-developmental IAV variants, but the strategy did not adequately address the technical risk associated with the MGS and NBCRV—particularly with integrating multiple Non-developmental Items and Government-furnished Equipment in a relatively short time period. *The Acquisition Strategy Report for the Interim Armored Vehicle* stated in several cases that "limited development activity may occur," and this did not take into account the tremendous challenges associated with systems integration (PM BCT, 2000, p. 10).

As an integrative approach for all program activities, the March 2000 acquisition strategy was overly focused on the eight production models. Ultimately, this led the program to leave out critical developmental steps such as systems integration in the interest of time. The importance of the systems integration process is crucial to risk mitigation because it reveals unpredictable interactions between components and validates the technical assumptions. The acquisition strategy clearly had a strong relationship to the MGS PMO's assumptions on NDI.

The unintended consequences of the acquisition reforms initiated by Dr. William Perry in the 1990s also affected the MGS. A broad assessment of these reforms, particularly the long-term cost savings, is beyond the scope of this case study. The DoD intended to improve the effectiveness and reduce the cycle-time of defense acquisitions through the use performance-specification reforms, but, in the early stages of their execution, they had the potential to increase the government's level of risk because of the disengagement from the contractor (Yoder, 2004, p. 2). While the emphasis on performance-oriented specifications provided the contractor with more latitude for innovation, it also created the potential for increased risk if the government did not identify an effective verification plan to accompany the performance specifications. The difficulty of obtaining waivers contributed to the government's disengagement from the contractor because the government had to put increased faith both in a well-thought-out verification plan that it stipulated in the EMD contract, as well as in the engineering approach taken by the contractor. The government wrote the MGS EMD contract with performance-based requirements and a nearly complete absence of military specifications and standards; in addition, the EMD contract did not call out specific requirements for component-level reliability testing with a systems engineering process (N. Jenny Chang, TACOM Reliability Engineer, personal communications, March 4, 2008).

c. Technical Risk Factors

The outer environment included two technical risk factors that were strongly interrelated: 1) the user focus on vehicle commonality and 2) the categorization of MGS as NDI. What made the MGS requirement particularly challenging was the user emphasis on commonality. Individually, the Army could have optimized on performance and reliability by developing separate pieces of equipment; however, the emphasis on commonality was a new concept, especially given the competing requirements of transportability and lethality. The Army was looking for a common vehicle to perform a wide range of tasks; however, the implementation of this concept proved to be a challenge. GDLS seemed to provide the optimal solution for the commonality requirement, with its 105mm equipped LAV III that initially appeared to be a non-developmental item.

General Shinseki's intent was to field a medium-force capability that consisted of off-the-shelf solutions. The emphasis on an off-the-shelf solution was a central element of the acquisition reforms of the 1990s described in the organizational risk factors. Although the MGS consisted of NDI components such as the chassis, C4ISR equipment, the low profile turret, and the Aries AHS, GDLS did not have an integrated solution at the time of the contract award. The categorization of the MGS as NDI was somewhat misleading because it did require significant modification. Although the NDI and commonality assumptions caused significant problems during development, both of these assumptions were closer to being a known-known rather than an unknown-known. In terms of information adequacy, the design of the time-based acquisition strategy caused the Army to overemphasize speed.

2. The Inner Environment

One can look at the MGS program symbolically as a "box within a box" that had to adapt to the risk factors of the dynamic outer environment (Simon, 1981, p. 148). The MGS PMO worked in an environment of considerable uncertainty while facing a time-based acquisition strategy. The objective of the inner environment is to achieve a sense of resilience or homeostasis. Through a series of self-organizing actions, the MGS PMO attempted to adapt the MGS program to the risk factors of the outer environment.

The new approach consisted of three inseparable elements that enabled the MGS program to manage the complex environment: 1) systems approach, 2) error-embracing behavior, and 3) collaborative learning. Although the systems approach is the decisive effort, it required the complementary effects of the two shaping efforts: error-embracing behavior and collaborative learning.

3. Systems Approach

The interdependent variables of the outer environment are difficult to separate and analyze as snapshots in time. For this reason, the decisive effort of managing complexity is the systems approach. The systems approach attempts to view the entire system in a holistic manner while coordinating people and processes. The problem of uncertainty becomes more difficult with acquisition programs that require the rapid integration of technology in a short time period.

Initially, the program operated under the assumption that the MGS would only require limited development. The MGS program viewed the use of systems engineering as either unnecessary or too time-consuming. As it became increasingly evident that the program would not meet the initial schedule and performance objectives, the use of systems engineering became a necessity.

Until 2004, the schedule consisted of a series of tests (PQT) that disproved all of the flawed assumptions from the beginning of the program. Rather than provide the Army with a well-integrated system in 2002, GDLS used the "big bang" approach to systems integration by piecing together all of the sub-systems at the same time (Hyunh, 2008, slide 20). The systems engineering process adopted by the MGS PMO and GDLS revealed that systems integration takes time and requires a disciplined process.

What the MGS PMO clearly understood was that the consequences of proceeding down the original trial-and-error approach were clearly not producing the desired result. The area in which this approach demonstrated unmistakable progress was in reliability growth for the AHS (see Figure 18).

Test Event	Date	Projected Reliability (MRBSA)	Actual Reliability (MRBSA)	Configuration/ Approach
Production Qualification Testing (PQT)	2003		13	-Original configuration -No component level testing -Trial & error approach leads to program crisis
Pre-Additional Reliability Testing (Pre-ART)	SEP-OCT 04	17	36	-Corrective Actions on original configuration -Transition to systems engineering
Additional Reliability Testing (ART)	NOV 04-JUN 05	27.8	N/A	-Corrective Actions on original configuration -Continue transition to systems engineering
Reliability Growth Testing (RGT)	JUL-AUG 05	44-55	57	-New AHS installed -Use of systems engineering
Production Verification Testing (PVT)	2006	81	104	-Production Configuration -Integrated strategic activities

Figure 18. Reliability Growth over Time
(GDLS, 2009)

In the trial-and-error approach, the MGS PMO hoped to achieve success during a relatively short PQT; however, this was a nearly impossible expectation. The implementation of a systems engineering approach played a major role in reducing the program's overall level of risk; in turn, this strengthened the Defense Acquisition Board's (DAB) confidence in the program (Wynne, 2004, p. 2). In complex programs that require personnel from multiple disciplines—such as the MGS—the use of systems engineering is critical to address problems from multiple perspectives with a holistic perspective.

4. Collaborative Learning

When developing a complex system, the effect of social influences—particularly collaboration—becomes increasingly important because one of the primary issues that arises is the lack of communication and knowledge dissemination between stakeholders (Prencipe, Davies & Hobday, 2005, p. 49). The systems engineering process takes social influences into account with its emphasis on interdisciplinary collaboration.

The organizational adaptations to accommodate the reliability growth plan (FPRB and DART) demonstrated the need for organizations to be highly proficient at monitoring and acting on the rapid flow of information. The effectiveness of collaborative learning demonstrates that the free flow of information is possible if the program leadership establishes a culture that identifies and eliminates defensive barriers.

One reason that the MGS PMO and GDLS took hold of collaborative learning was that the program reached the crisis point. Defensive barriers came down, and both the MGS PMO and GDLS saw it as an opportunity to get the program on track. In this case, the crisis period of late 2004 served as an innovation opportunity for both GDLS and the MGS PMO to establish a new learning network (see Figure 19).

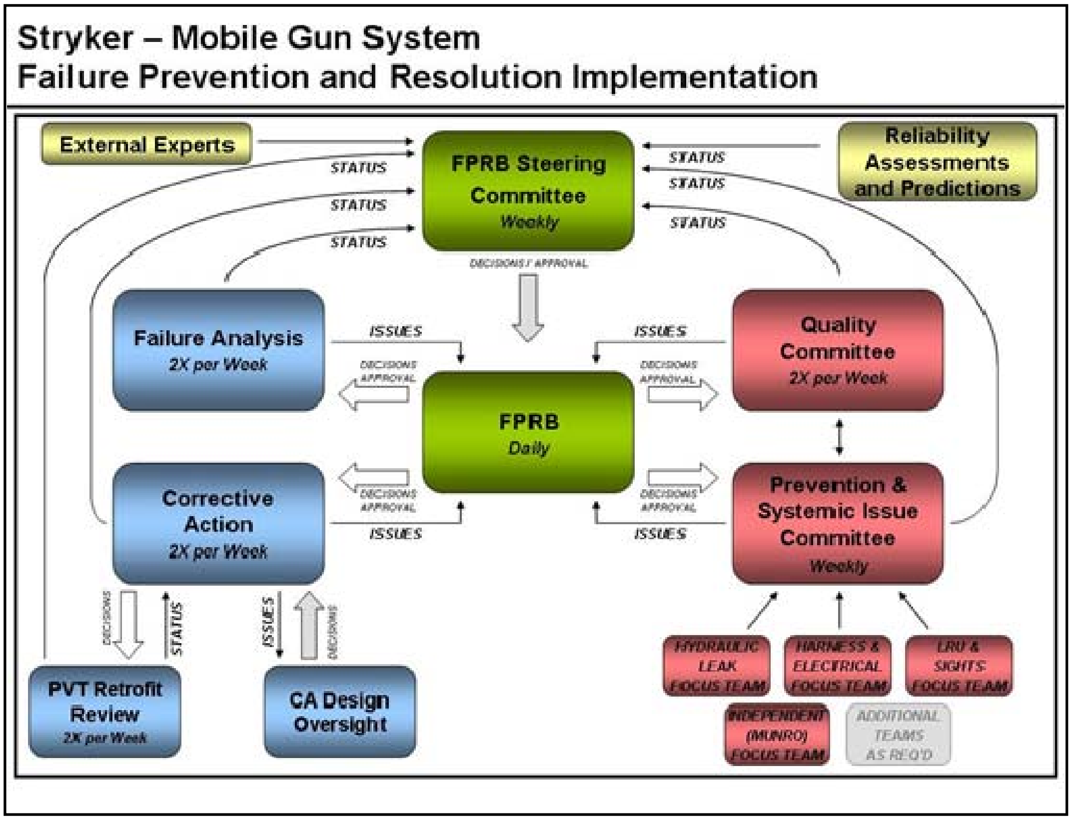


Figure 19. Example of Collaborative Learning
(GDLS, 2007, slide 5)

Additionally, complex programs must deal with information that falls under the known-known, unknown-known, and unknown-unknown categories. Risk management is practical with known-known and unknown-known information, but it is not as effective with unknown-unknown events because these events are almost impossible to predict. That is one reason why it is essential for organizations to have a collaborative learning capacity that enables them to adapt to unpredictable situations. The capability for organizations to adapt to ill-structured and unpredictable problems makes collaborative learning a critical and complementary effort to the systems approach and to error-embracing behavior. The use of the Failure Prevention and Review Board (FPRB) and IPTs demonstrated that reduction of cycle-time with the reliability growth is possible through a collaborative and disciplined effort.

Recognizing the importance of social factors in the implementation of systems engineering, the MGS PMO and GDLS realigned their organizations in late 2004 to improve their level of collaboration and ability to implement the systems engineering process. However, the systems approach and collaborative learning requires a culture in which the program leadership rewards individuals for identifying problems and developing integrated solutions.

5. Systematic Error-embracing Behavior

An overall strategy that integrates the use of systematic, error-embracing behavior with the systems approach and collaborative learning provides a complex program with the means of determining how components and sub-systems will interact. Initially, the MGS PMO and GDLS development approach was to simultaneously bring many components together and hope that the tests were successful. As it became more apparent that the design was immature, the primary method to reduce the knowledge gap between actual and expected performance was to seek error-embracing behavior in the form of identifying and correcting failure modes.

The MGS PMO developed a path for reliability growth that started with pre-ART and concluded with PVT. The MGS PMO applied the lessons learned from PQT by going directly to systems-level testing and then conducting a series of component-level tests on the new Western Design AHS and other design improvements. One reason that the reliability growth was so successful in 2005-2006 was the systematic identification of failure modes. The MGS PMO and GDLS identified failure modes in a small enough scope to diagnose them and develop corrective actions in a methodical manner.

G. Conclusion

To the outside observer, it may seem as though the Army and GDLS did not exercise enough due diligence with the development of the MGS. In retrospect, that observer may realize that no one is omniscient, and individuals have tremendous difficulty in making objective comparisons across multiple options while trying to figure out the consequences of those decisions (Simon, 1979, September, p. 502). In *Judgment Under Uncertainty*, Tversky and Kahneman also discussed this concept when they said, "People rely on [a] limited number of heuristic principles, which reduce the complex tasks of assessing probabilities and predicting values to simpler judgmental operations. In general, these heuristics are quite useful, but sometimes they lead to severe or systematic errors" (1974, September 27, p. 1124).

A perfect adaptation to the outer environment is nearly impossible for many reasons but mainly because the decision-makers, the MGS PMO in this case, were operating under uncertainty. To make the best decisions possible, the decision-makers needed as much fact-based information as possible to establish their baseline. With the MGS, the Army initiated the program with imperfect information based on inaccurate assumptions in the interest of time. The future occurrence of a similar situation is preventable if the lessons learned are properly absorbed.

There is no simple answer to a root-cause analysis on the troubled development period of the MGS from 2001-2008. It seems evident that the Army and GDLS satisficed in their development strategy to meet the time-to-market requirements. Moving beyond the actual system reliability, this case study examined the structure of processes to determine how an overestimation of the system reliability occurred.

In effect, the government made decisions early on about the length of the schedule and the test approach that did not reflect the technical status of the system, and the government anchored these decisions on inaccurate assumptions about the MGS. In retrospect, it appears that the Army started off with a tendency for unwarranted optimism that the MGS PMO and GDLS could field the system on the original schedule. That optimism did not take into account the lessons that time-to-market is not free and that systems integration takes time. The last two chapters demonstrated that a rigorous and well-resourced systems engineering process is the most effective way to reduce technical risk in the face of uncertainty.

All of this points to the need for organizations to deal with uncertainty, particularly within complex systems. Within defense acquisition, the solution to a problem is not only dependent upon the objective information provided to the decision-maker but also upon the type of process that the decision-maker uses. A decision-maker must determine what he or she knows about a system and must then determine how much information is sufficient, given the availability of time and resources. The next chapter addresses the lessons learned from the MGS case study on managing complexity.

THIS PAGE INTENTIONALLY LEFT BLANK

VI. Conclusion and Lessons Learned

A. Introduction

One of the stated goals of the Defense Acquisition System (DAS) is to provide users with "effective, affordable, and timely systems" that are developed in "response to an approved need" (Under Secretary of Defense (AT&L), 2003a). The Army provides program managers with a charter to field these systems given cost, schedule and performance constraints while navigating a complex environment. The difficulty in fielding systems stems from the complex environment found in the defense acquisition system. The environment is complex because of the difficulty in determining how the risk factors are interrelated. Environments that encounter a greater degree of complexity and uncertainty will also experience an increase in their overall level of program risk. The MGS case study attempts to document how one program managed that complex environment.

"Manage" is the key term because program managers cannot eliminate uncertainty and complexity, but they can manage it, if they have an adequate strategy in place. In *Embracing Uncertainty*, Clampitt and DeKoch (2001) describe five methods for creating certainty that include gut instincts, experiences, reasoning, and testing (p. 47). Yet, in their analysis, they debunk the notion that one can eliminate uncertainty in decision-making (Clampitt and DeKoch, 2001, p. 28). In *The Fifth Discipline*, Senge discusses the misleading notion that effective managers must have an omniscient picture of what is occurring around them at all times when he said, "[I]t is simply unacceptable for managers to act as though they do not know what is causing a problem […] Those intent on reaching such positions learn early on to develop an air of confident authority" (2007, p. 234).

This case study makes it evident that charting a course of certainty in all but the most simple acquisition programs is not possible given the tremendously complex environment faced by today's program managers. The MGS program experienced complexity in terms of organization, environment, and technology. It is no surprise that program managers frequently use the cliché "it depends" when describing a solution to a problem. The program manager does not base his or her response on a scientific analysis of the problem, but, rather, the program manager bases the response on years of observing unpredictable interactions between complex events.

Although the pursuit of absolute certainty is a quixotic program objective, a more pragmatic objective for program managers is the management of complexity. What follows is a restatement of this case study's research question, a discussion of the core findings, and a modest list of lessons learned.

B. Research Problem

The primary research problem was to find a significant developmental problem experienced with the MGS and then to analyze the root causes of the problem as well as the corrective actions taken by the MGS Product Management Office (MGS PMO). Parallel to this effort, this case study explored complexity theory to determine if it was applicable to the MGS program. After conducting the analysis, this case study attempted to draw insights on how the MGS program managed complexity and then to determine what lessons could be applied to other acquisition programs.

C. Findings and Application

1. Findings

The Army planned to acquire the MGS under an accelerated, time-based acquisition strategy. However, the acquisition strategy did not achieve the early fielding of the MGS, which was one of the Army's primary objectives. The acquisition strategy is the "high level business and technical management approach designed to achieve program objectives within required resource constraints" (DSMC, 1999, 1-1), but the IAV acquisition strategy did not account for the technical difficulties encountered in transitioning from the early MGS variants to the production version.

The Army took a number of steps to mitigate program risk to accommodate the time-based acquisition strategy. In 1999, the Army conducted a Platform Performance Demonstration (PPD) to determine the “state of the art,” and it used the information gained from the PPD to refine the requirements and develop the Request for Proposal (RFP). The Army also mandated that the MGS use NDI components to limit the amount of development required.

Despite the steps taken to reduce programmatic risk, the MGS still required a considerable amount of development. It was not until 2002 that the Army realized there was a gap between the expected or anticipated performance of the MGS and its actual performance. The early MGS variants were less technically mature than anticipated, and this required additional time for development and testing.

What makes the MGS program interesting as a case study was the rate of improvement in the MGS reliability after the strategic approach changed. This case study used the MGS reliability problems as a microcosm for analyzing how a contemporary acquisition program self-organized to increase its adaptation to complexity. During the crisis period of 2004-2005, the MGS PMO adopted a systems approach complemented by error-embracing behavior and collaborative learning.

The systems approach adopted by the MGS PMO and GDLS improved the capacity of the program to self-organize when the complex environment around the program was constantly changing. The MGS PMO realized that the technical progress of the vehicle was out of alignment with the acquisition strategy, and it took steps to redefine the strategy through the integration of the systems approach, error-embracing behavior, and collaborative learning.

Based on the information available, the case study concluded that intensive programmatic crises occur when an acquisition strategy does not adequately synchronize critical program activities such as risk management, systems engineering, test and evaluation, contract management, and integrated product/process development. These factors strongly correlate to the success factors that are associated with the actions taken by the MGS PMO and GDLS (see Figure 20).

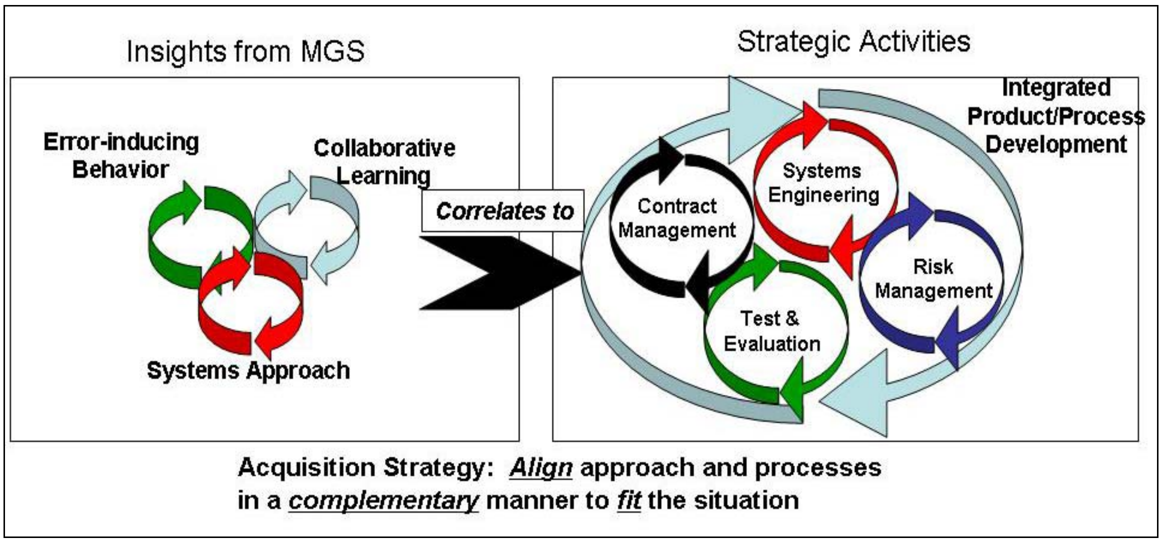


Figure 20. MGS PMO Strategic Approach

Programs that embrace a systems approach complemented by error-embracing behavior and collaborative learning are capable of accepting greater degrees of risk associated with uncertainty and complexity. These concepts are not new. In fact, defense acquisition doctrine has a deep and broad array of explicit knowledge available to acquisition programs that discusses these concepts, but it is unclear how of much of this doctrine is adhered to. Furthermore, it is unclear if lessons learned from other programs such as the Army's Sergeant York air defense system, the Navy's T-45 flight trainer, and the Army's Armed Reconnaissance Helicopter are fully absorbed by the acquisition community.

2. A Strategic Approach is Necessary to Manage Complexity

External and internal complexity results in increased downstream levels of uncertainty for acquisition programs. Managing uncertainty is possible through continuous strategic planning that ascertains the level of information available from the environment and integrates program activities to achieve objectives while recognizing resource constraints. Over time, the problems caused by complexity will change, and the program manager must make corresponding adjustments to the strategy. Between 2000 and 2006, the MGS PMO self-organized to improve the alignment and fit of its strategic activities (see Figure 21).

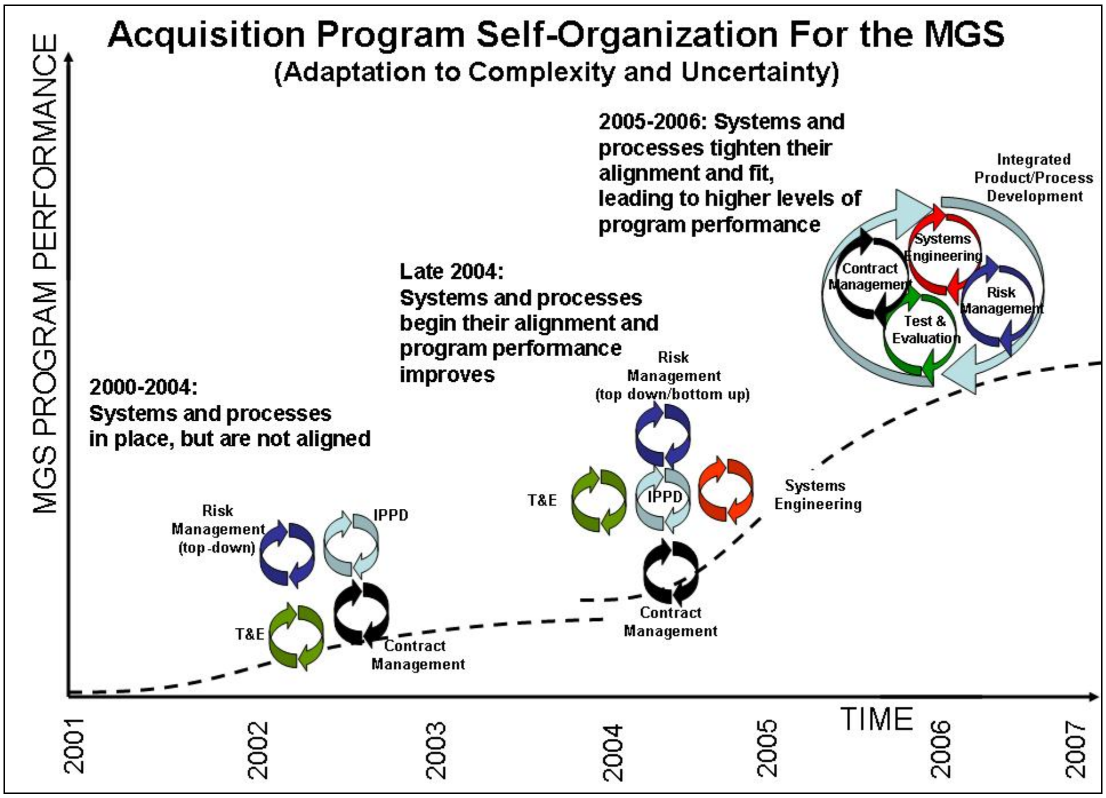


Figure 21. MGS Acquisition Strategy Alignment over Time

How does a program manager proactively determine his/her strategic approach? It is essential to point out that acquisition strategy is not a static program document that the program manager updates at key milestones. Rather, acquisition strategy is a continuous process that the program manager uses to integrate all elements of his or her program, while recognizing the risk and uncertainty in the complex environment.

The key elements of an acquisition strategy will not align by default. Rather, self-organization is an adaptation to complexity that requires significant effort and foresight. The program manager should start with the program's internal and external goals, and then align the program's activities to fit those goals. After achieving some alignment, the program manager will need to reinforce the fit between elements. Therefore, the program manager must often take on the roles of an orchestrator and synchronizer.

3. Integration of Strategic Activities

The difference in program outcome could originate from the program manager's ability to develop an acquisition strategy that adapts to the environment through the alignment and fit of its strategic activities. The acquisition strategy should serve as a means to coordinate the work of all individuals who work for or with the program. As a dynamic planning document, it should ensure that the program's activities reinforce one another and are consistent.

With acquisition strategy, the whole matters more than any individual activity. At the core of strategic planning for acquisition programs is the alignment of these five elements: integrated product/process development, risk management systems engineering, test and evaluation, and contract management. There is no cookie-cutter approach or template for strategy implementation because each case is unique. When properly tailored to a common strategic vision, these activities become powerful tools to manage complexity.

a. Integrated Product/Process Development (IPPD)

The use of Integrated Product/Process Development provides the overarching linkage between the strategic activities because it enables collaborative learning and cross-functional communication. A key element of IPPD is the use of multi-disciplinary Integrated Product Teams (IPTs). The use of these teams is essential because each stakeholder provides a unique frame of reference and set of assumptions. Within the acquisition strategy, the program manager must properly orient and challenge the IPTs towards program objectives and empower them to reduce defensive barriers between functions and organizations (DSMC, 1999, p. 2-3).

An IPT system and a program culture that emphasize collaborative learning will also help a program adapt to unknown-unknown risk factors. Unknown-unknown events can strike a program without warning, and a program's ability to quickly adapt, learn, and develop collaborative solutions provides the most effective means to adapt to this type of risk factor. The IPTs serve as the facilitators of all strategic activities for the program.

b. Risk Management

The risk management process is dependent upon the program's IPTs because the program requires multiple perspectives for risk identification. The DoD *Risk Management Guide* clearly states that risk identification is the responsibility of all members of the IPT, and it does not solely rest with the program manager or with the lead systems engineer (DoD, August, 2006, p. 7). The identification of risk encompasses all aspects of the acquisition program, to include organizational, environmental, and technological aspects. Risk management incorporates the concept of feed-forward, which Herbert Simon discussed as a key element of self-organization in *The Sciences of the Artificial* (1981, p. 44).

The MGS program demonstrated that a limited self-organization is possible in the midst of a crisis, but this approach requires a substantial commitment of resources and, most importantly, organizational support. While there is no way to anticipate all risk, the program manager should ensure that the acquisition strategy integrates the risk management process with the systems engineering process. A risk management process that identifies risk from both the bottom up and top down will help a program manager anticipate problems before they occur and achieve greater stability and resilience.

c. Systems Engineering

Risk management is a key element of DoD acquisition doctrine that complements the systems engineering process. Like acquisition strategy, systems engineering covers all aspects of the program, but it primarily supports the acquisition strategy by establishing a common approach to the coordination of multi-disciplinary activities and processes.

The use of the systems engineering process enables the program to develop a holistic view of development. The systems engineering process provides the overall plan that integrates both technical and business aspects of the program. Like the other strategic activities, the systems engineering process is dependent upon the program's IPTs for the dissemination and interpretation of information. Timely and accurate decisions also depend upon accurate snapshot assessments of a system through test and evaluation.

d. Test and Evaluation

Test and evaluation is the program manager's best method of determining the program's actual technical status. Test and evaluation supports the acquisition strategy by assisting the program manager with revealing technical unknowns, which reduces the program's overall level of risk. A program that establishes a culture in which test and evaluation is an error-embracing process will view failures as critical to the learning process and continuous improvement. Therefore, error-embracing behavior should not take the form of a go/no-go or pass/fail test because this mindset will inevitably lead to unintended consequences. These consequences may include hiding bad results or limiting the scope of testing. All of the stakeholders, including the contractor, should take the perspective that embracing relevant failures will ultimately lead to an improved design that meets the user's needs.

e. Contract Management

Contract management supports acquisition strategy by shaping the contractor's behavior to achieve the program's objectives. It is also dependent upon an effective risk management process to ensure that the government and the contractor properly share risk. When planned and executed properly, contract management ensures that the processes used by the government and contractor are synchronized. Contract management is also the most tangible means of communicating the program manager's strategic intent to the contractor. The program manager should also ensure that all of the program's IPTs include a contract representative so that the contract can adapt to any changes to the environment in a timely manner.

D. Lessons Learned

What follows is a short discussion of lessons learned and recommendations gleaned from this case study on MGS and its use of NDI. The inclusion of particular actions in these lessons and recommendations does not necessarily imply their absence or failure in the MGS program. Due to time and space constraints, the case study could not address all aspects of the program. Regardless, the intent of the lessons learned and recommendations is not to list what went wrong with the MGS, but rather to use the benefit of hindsight in a constructive manner and disseminate actionable items that are useful for any acquisition program.

1. To manage complexity, a program requires an acquisition strategy that is adaptable to the changes in the external and internal environment.

a. Discussion: Complexity originates from outside of an acquisition program and each element of complexity interacts and influences a program through multiple risk factors. By itself, a risk factor may not pose a problem, but when multiple risk factors interact, a disaster may result. The central issue with complexity is uncertainty. Program management offices that find themselves caught in the cauldron of fire-fighting problems with a crisis management approach have lost the initiative. From 2002 to 2004, the MGS program demonstrated a fire-fighting mentality in reaction to a number of developmental problems that included reliability shortfalls. The reliability problems were partly a symptom of the program's inadequate acquisition strategy, which did not address the risk factors specific to the MGS.

The ultimate objective of a program is to field a system, but this requires the program manager to create an acquisition strategy that can manage a broad continuum of uncertainty. The MGS PMO was able to reestablish the initiative after reinvigorating their systems engineering process through effective error-embracing behavior and collaborative learning. One factor that allowed this to occur was the institutional support that the MGS had from the user.

b. Recommendations**:**

- *Program managers should develop and empower a strong IPPD because shared perspectives and interpretations across disciplines and processes is the key to managing complexity*. Program managers should conduct periodic assessments of the operating environment assumptions and risk factors with key stakeholders.

- *Program managers should dedicate blocks of time on a recurring basis for a review of their program's strategy*. Program managers should dedicate one day two times per year to discuss the program's acquisition strategy. The program manager should discuss a component or activity of the acquisition strategy on a monthly basis as an action item.

- *Program managers should form an informal Tiger Team or group of advisers to challenge program acquisition strategy***.** Program managers should form a diverse group in an informal advisory role to meet periodically to discuss how a program's strategy is meeting its objectives. The purpose of this group is to challenge and question the program manager in an effort to improve the resilience and quality of the strategy.

- *Acquisition strategy should focus on synchronization of activities*. Beyond discussing strategic activities such as systems engineering, risk management, test and evaluation, contract management, and IPPD as separate events, the acquisition strategy should describe how the program should synchronize activities to achieve program objectives.

- *Program managers should communicate the program's acquisition strategy continuously to allow for greater decentralized decision-making capacity and alignment of program objectives*.
- *During Acquisition Planning, program managers should include the acquisition strategy with the Request for Proposal (RFP) to increase the contractor's awareness of the program's approach.*

2. Systems integration is always something new, and the effort it requires is frequently underestimated. The materiel developer should allot adequate time for systems integration during its development.

a. Discussion: During its initial development period, the MGS PMO and GDLS did not use an adequate systems engineering process. One consequence was that the program did not have a clear picture of the technology readiness of the MGS Mission Equipment Package (MEP), particularly the ammunition handling system. The MGS required the integration of several major components, including the low profile turret, the 105mm main gun, the ammunition handling system, and the fire control system. The MGS MEP was less technically mature than the MGS PMO anticipated, and this contributed to schedule delays and more testing. The MGS PMO soon determined that the integration of the major components required a more robust systems engineering process.

b. Recommendations

- *During acquisition planning, the program manager should establish a Systems Engineering IPT (SEIPT) to oversee all technical planning.* After awarding the contract, the SEIPT should become the Systems Engineering Integration Team that works across all IPTs to address technical aspects of the system.
- *Prior to publishing the RFP, the program manager should ensure the program identifies potential high-risk requirements and/or Work Breakdown Structure components.*
- *During Source Selection, the government should prioritize the contractor's technical capabilities, particularly systems engineering, under Section M of the RFP, Evaluation Factors.* Additionally, the government should ensure that it uses a highly experienced lead systems engineer when evaluating the contractor's technical capabilities.

- *The program manager should state within the Statement of Objectives (SOO) or Statement of Work (SOW) that the contractor's systems engineering processes must be compatible with the government's processes.*

- *The SOW/SOO should mandate the use of an integrated government/contractor configuration management process*. Each engineering change can potentially trigger new problems. With engineers from multiple organizations working on the system, the program manager should emplace a disciplined configuration management plan that allows the program to diagnose problems during systems integration.

- *The program manager should make the contractor's systems engineering plan a Contract Data Requirement List (CDRL) item.*

- *If the system requires development, then the RFP should require an assessment of technical readiness levels and integration readiness levels down to the third or fourth level of the Work Breakdown Structure.*

- *The DoD should augment the Technical Readiness Assessment with an independent Integration Readiness Assessment.* The Integration Readiness Assessment should provide a measureable Integration Readiness Level (IRL) that assists with determining the effort required for systems integration.

- *Program managers should approach systems integration as a bottom-up activity.* Program managers should embrace a technical approach that integrates components on a small enough scale so that the program can discover problems as early as possible with sufficient time to diagnose them.

3. The program manager should integrate a top-down/bottom-up risk management process with the systems engineering process.

a. Discussion: Uncertainty is the fundamental problem for acquisition programs, and much of this uncertainty comes from the unpredictable interaction of risk factors. Program managers should not underestimate the importance of risk management, particularly in the early stages of a program. Systems engineering provides an integrated and multi-disciplinary approach to address a range of elements from the external continuum of factors, and a program should accompany systems engineering with an equally strong risk management process. *The Risk*

Management Guide for DoD Acquisition clearly summarizes this idea, "Additionally, risk management is most effective if it is fully integrated with the program's systems engineering and program management processes—as a driver and a dependency on those processes for root cause and consequence management" (DAU, August, 2006, p. 1).

Like the systems approach, risk management requires collaborative learning not only between the government and the contractor, but also with other key stakeholders such as the test and user communities. The ability to absorb a broad range of risk requires the program manager to anticipate problems, many of which fall into the unknown-known category. With unknown-known information, someone in the program may have the information that the program manager needs for a decision. Therefore, it is essential that the risk management process use both a top-down and a bottom-up approach to risk identification.

In hindsight, it appears that the Army did not effectively employ a bottom-up risk management process at the beginning of the MGS program. Two potential reasons stand out for this shortfall. First, the MGS PMO did not have adequate staffing to conduct the risk management process given their involvement in the Interim Armored Vehicle source selection. Second, the IPT structure was not fully functional early in the program.

b. Recommendations

- *The program manager should incentivize the contractor to integrate its risk management process with the government's process.* The integrated risk management process between the government and the contractor should collaborate as much as possible on information and common metrics.
- *The program manager should ensure that the contractor's risk management plan is a CDRL item, and that program integrates it with the systems engineering plan.*

- *Government PMOs should empower the contractor throughout the risk management process in order to share risk and take ownership of the process*.

- *The PMO should ensure that the Risk Management IPT has a written charter that it supports with Memorandums of Understanding/Agreement between other governmental organizations/agencies and that it codifies within the contract*.

- *The program manager should establish a risk management coordinator who works with the program's IPTs to identify risk.* The risk management coordinator should assist the program manager with the risk management process.

- *The program manager should ensure that the lead systems engineer reviews the risk mitigation plans, and the PMO should routinely update these plans*. The program manager and lead systems engineer should carefully review the mitigation plan to determine the potential impact to other parts of the program.

- *The PMO should run a Risk Management Board on a recurring basis to review the risk management process and advise the program manager on risk.*

- *Programs should make identified risks available to all stakeholders on a shared and collaborative database to improve risk visibility and program transparency*.

4. The integration of multiple NDI/COTS components will likely increase programmatic complexity. Program managers should carefully review the risks associated with materiel solutions that require the integration of NDI/COTS.

a. Discussion: During the contract award briefing, LTG Kern, the Source Selection Authority stated:

> The mobile gun system takes a 105mm cannon which we already have and integrates it into the LAV chassis with a turret. And so off-the-shelf, in the context that we are speaking of, it means that there are integration efforts required for development, but we aren't designing new guns, sights, or sensor packages for this equipment. (Federal News Service, 2000)

A common misconception is that the use of NDI/COTS components correlates to a decrease in technical risk. However, program managers should carefully consider the risks associated with NDI/COTS. The IAV acquisition strategy mandated the use of NDI/COTS to reduce the technical risk (PM SBCT, 2006, p. 106; PM BCT, 2000, p. 8). With the MGS, the integration of multiple NDI/COTS increased the technical complexity because none of these components was plug-and-play, and all required modification.

Unless a system is immediately ready for fielding, meaning that it is truly off-the-shelf and immediately available, it will frequently require some level of development. The MGS proved that systems integration is unpredictable. Yet, a time-based acquisition strategy requires a much greater degree of certainty than the more typical event-based acquisition strategies. Applying a time-based strategy to a program that requires system development may successfully induce a greater sense of urgency, but it still imposes an arbitrary deadline on system fielding that does not reflect reality.

b. Recommendations

- *During acquisition planning, the program manager should thoroughly conduct market research on NDI/COTS and carefully consider the trade-offs required in test and evaluation and schedule*. Analyzing these factors will help the PM reduce risk.
- *Program managers should verify the contractor's test and evaluation processes for NDI/COTS prior to contract award*. Government verification of contractor testing is necessary because the contractor testing may not replicate the item's performance in a combat environment, and it may not replicate the military's intended use of the item.
- *If the item is purely NDI or COTS, then the program manager should place the preponderance of contractual risk onto the contractor since the system is technically mature.*
- *The program manager should ensure that the contract SOW or SOO clearly describes the means of verification for performance specifications.* Program managers should consult with multiple agencies on the most effective and efficient means of verifying performance specifications.

- *The PMO should ensure that it receives the Technical Data Package for all NDI to improve flexibility with systems integration, future upgrades, and logistical sustainment.*

- *Programs should avoid combining developmental and non-developmental variants under the same acquisition strategy.* Programs that require a developmental effort need a unique acquisition strategy that necessitates a different set of trade-offs in cost, schedule, and performance.

- *After verifying the contractor's testing process for NDI/COTS, the government should tailor the test and evaluation process around conditions not addressed by the contractor.*

5. The materiel developer, user, contractor, and test and evaluation communities should develop a culture of error-embracing behavior as the centerpiece of effective test and evaluation.

a. Discussion: During the early stages of MGS delivery in 2002 and PQT in 2003, it became apparent that the ammunition handling system had significant problems, yet the Army did not verify these problems until much later in PQT (LTC Shane Fullmer, personal communication, February 27, 2009). Ultimately, the Army did not fully address these problems until late 2004—almost two years later. After the MGS PMO placed a high priority on improving the reliability of the MGS MEP, the test program achieved disciplined flexibility. When it became apparent that additional reliability growth was necessary, the PMO adjusted the Production Verification Test to allow for greater Reliability Growth Testing. The approach of disciplined flexibility allowed the PMO to address reliability shortcomings.

Error-embracing behavior goes beyond test and evaluation because it requires an aggressive organizational drive to find and root out system failures. A variation of this lesson learned is to confront the brutal facts as early as possible and to reduce the tendency to make less of problems. Clearly, test and evaluation is a continuous part of the systems engineering process, and it is a means of resolving whether the actual performance is meeting the expected performance. Error-embracing behavior is an attitude that discovery of test failures is desirable because the developer is learning how to improve the system design.

b. Recommendations

- *The program's test and evaluation strategy should complement the acquisition strategy by uncovering as many technical unknowns as possible*. The structure of the test and evaluation strategy should provide the program manager with incremental amounts of information that will lead to improved decision-making.

- *The Test and Evaluation Master Plan (TEMP) should allow for flexibility.* If the government believes that a particular component, particularly a critical element of a Mission Equipment Package, is inadequate, then the test program should address the problem as soon as possible.

- *The Measures of Suitability outlined in the TEMP should adequately reflect the Operational Mission Summary/Mission Profile (OMS/MP) and they should provide a direct measurement of reliability, particularly for critical, high-risk components*.

- *Program managers should have incentive systems, both internal and external to the program, to create a culture in which the early identification of problems and issues is highly encouraged*.

- *Program managers should implement event-based test and evaluation that reflects the anticipated maturity of the system***.** Programs must verify the effectiveness and suitability of individual components before moving onto system-level testing.

6. Inadequate early and continuous planning for reliability leads to longer acquisition cycle-times and higher lifecycle costs.

a. Discussion: The MGS program experienced a crisis period in 2004-2005 primarily because the reliability of the Mission Equipment Package fell short of the user's requirements. The poor reliability was the result of an abbreviated systems integration process and a test and evaluation process that did not reveal reliability problems early enough. The MGS is not alone in demonstrating inadequate reliability, and one Army Test and Evaluation Command study of defense systems demonstrated that only 20% of the systems that underwent operational reliability testing from 1996-2000 met the reliability requirements (DoD, 2005, pp. 1-3).

After attempting a test for reliability approach in 2003, the MGS PMO developed a design for reliability approach in 2004-2005. Additionally, the MGS PMO and GDLS implemented an improved Reliability Growth Testing process that incorporated a better tracking system for failure modes and a faster implementation of corrective actions. The MGS PMO and GDLS also integrated a design for reliability approach with the systems engineering process.

b. Recommendations

- *During acquisition planning, the government should conduct an adequate engineering analysis of items identified during market research to determine the extent of integration required and the potential impact on system reliability*.
- *The program manager should utilize the TRL/IRL assessment as an indicator of a potential problem with design for reliability.* The TRL/IRL assessment should trigger an early focus on component-level testing.
- *Within the RFP, the program manager should include a Reliability Program Plan (RPP) that discusses the requirements for reliability and design for reliability approach*. The RPP should require the contractor to provide a conversion of the reliability performance stated in the Operational Mode Summary/Mission Profile (OMS/MP) and Failure Definition/Scoring Criteria (FD/SC) to detailed specifications (Chang et al., 2009, p. 153). The RPP should also document the organizational roles and responsibilities for reliability activities, and the procedures for verifying reliability requirements—to include contingency plans for improving reliability (Office of the Deputy Under Secretary of Defense (A&T), 2009, p. 30).
- *Future programs should adopt a design for reliability approach*. If the program adopts an off-the-shelf system that requires systems integration, then the program manager should incorporate design for reliability into the systems engineering and test and evaluation plans because it will ultimately reduce the total ownership cost.
- *The program manager should ensure the use of a closed-loop reporting system.* The closed-loop reporting system ensures that the developer can properly record, track, and correct failure modes. The formation of a Failure Prevention and Review Board (FPRB) ensures that the developer can identify and address failure modes in a timely manner.

E. Recommendations for Further Research

1. During the MGS development, requirements changes occurred, starting in 2004. These requirements changes resulted in several Configuration Steering Boards (CSBs). The purpose of the Configuration Steering Board is to serve as an oversight committee that reviews requirements changes that have the potential of causing cost or schedule changes to ACAT I programs (Young, 2007). Research is necessary to determine the root cause of the requirements changes and how the MGS PMO addressed the challenge. How does a program, like MGS, establish requirements discipline and limit configuration changes?

2. Do contemporary acquisition programs properly align their strategic activities? Do these programs use the systems engineering, risk management, test and evaluation, contact management and IPPD processes in a complementary and reinforcing manner?

3. Overcoming obstacles in the development effort can cause considerable delays and, depending upon their size and priority, can also increase the program's cost. Contractors are success-oriented and are anxious for the government to fully adopt their proposals and design solutions. The contractor has a natural tendency to make less of a developmental problem. How does the government, which is typically understaffed, diagnose the judgment of the contractors to determine the actual maturity of a system at the beginning of system development or during source selection? Does the government currently have the resources, including human capital, to conduct this effort?

4. One option for programs that require a time-based approach is to conduct a non-linear approach to system development, in which the materiel developer, contractor, user, and the test community collaboratively agree under the auspices of the DoD to conduct parallel efforts. In the case of MGS, this might include building additional prototypes to allow for a broader test effort. The broader test effort would allow for simultaneous testing of multiple test events that normally

occur in sequence. While this process would be more chaotic and “messier” to manage, it *might* reduce the cycle-time of development. Such an effort would require multiple waivers from the DoD as well as sufficient resources early on. Has the DoD developed a program using this approach? Is this approach feasible?

List of References

Andrews, B.A. (2004, April 30). *Joint warfighting concept development conference*. Briefing. Presented at the Joint Warfighting Concept Development Conference. Retrieved December 21, 2008, from www.dtic.mil/jointvision/concept_development.ppt

Army Materiel Systems Analysis Activity (AMSAA). (2000, September). *Reliability growth guide*. Retrieved April 24, 2009, from http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA381985&Location=U2&doc=GetTRDoc.pdf

Baumgardner, N. (2000, April 7). *IAV RFP awaiting final approval by Shinseki.* Retrieved November 19, 2008, from http://findarticles.com/p/articles/mi_6712/is_5_206/ai_n28767940

Baumgardner, N. (2000, April 10). Army releases IAV RFP. *Defense Daily, 206*(6). Retrieved November 21, 2008, from http://www.lexisnexis.com.libproxy.nps.edu/us/lnacademic/search/homesubmitForm.do

Baumgardner, N. (2003, May 23). Army, GD implementing Stryker MGS changes for limited user testing. *Defense Daily*, *218*(39). Retrieved November 21, 2008, from http://www.lexisnexis.com.libproxy.nps.edu/us/lnacademic/search/homesubmitForm.do

Baumgardner, N. (2003, July 10). GD official: Stryker mobile gun system testing on track for LRIP decision. *Defense Daily*, *219*(7). Retrieved November 21, 2008, from http://findarticles.com/p/articles/mi_6712/is_7_219/ai_n29020254/

Bell, B.B. (1999, November 18). *Platform performance demonstration memorandum for record to industry professionals*. Federation of American Scientists.org. Retrieved December 1, 2008, from http://www.fas.org/man/dod-101/sys/land/docs/bct/Platform.pdf

Blanchard, B., & Fabrycky, W.J. (2006). *Systems engineering and analysis* (4th ed.). Upper Saddle River, NJ: Prentice Hall.

Censer, M. (2008, April 15). Army wants Gates to waive Congressional requirement on Stryker's readiness. *InsideDefense.com*. Retrieved November 21, 2008, from http://www.insidedefense.com/secure/display.asp?docnum=4152008_april15b&f=defense_2002.ask

Censer, M. (2008, May 19). Senate panel calls for Stryker MGS to undergo additional testing. *InsideDefense.com*. Retrieved December 1, 2008, from http://www.insidedefense.com/secure/display.asp?docnum=ARMY-20-20-6&f=defense_2002.ask

Chairman of the Joint Chiefs of Staff (CJCS). (2007a, May 1). *Joint capabilities integration and development system* (CJCSI 3170.01F). Washington, DC: Author. Retrieved February 10, 2009, from http://www.dtic.mil/cjcs_directives/cdata/unlimit/3170_01.pdf

Chairman of the Joint Chiefs of Staff (CJCS). (2007b, May 1). *Operation of the joint capabilities integration and development system* (CJCSM 3170.01C). Washington, DC: Author. Retrieved April 20, 2009, from https://acc.dau.mil/CommunityBrowser.aspx?id=28862

Chang, N.J., & Rohall, D.J. (2008, September). Improving program success by applying systems engineering and reliability growth analysis, *The ITEA Journal of Test and Evaluation*. Retrieved February 10, 2009, from http://www.itea.org/files/2008/2008%20Journal%20Files/September%202008/jite-29-03-02.pdf

Chang, N.J., Rohall, D.J., Tananko, D.E., Kumar, S., Paulson, J., & Ruma, J. (2009, March). Reliability growth of the mobile gun system during production verification test. *The ITEA Journal of International Test & Evaluation*. Retrieved March 15, 2009, from http://www.itea.org/files/2009/2009%20Journal%20Files/March%202009/jite-30-01-149.pdf

Clampitt, P., & DeKoch, R.J. (2001). *Embracing uncertainty: The essence of leadership*. Longon, England: M.E. Sharpe.

Conahan, F.C. (1986, May). *Sergeant York: Concerns about the army's accelerated acquisition strategy*. Retrieved January 15, 2009, from http://archive.gao.gov/d4t4/130223.pdf

Dawson, S. (2001, June). *A case study on acquisition reform: Brigade combat team, the vanguard for Army transformation* (Master's Thesis). Monterey, CA: Naval Postgraduate School.

Defense Acquisition University (DAU). (2003, June). *Acquisition strategy guide* (5th ed.). Fort Belvoir, VA: Defense Acquisition University Press.

Defense Acquisition University (DAU). (2006, August). *Risk management guide for DoD acquisition* (6th ed.). (Version 1.0). Fort Belvoir, VA: Defense Acquisition University Press. Retrieved April 7, 2009, from http://www.dau.mil/pubs/gdbks/docs/RMG%206Ed%20Aug06.pdf

Defense Acquisition University (DAU). (2009a). *Failure definition and scoring criteria (FD/SC)*. Retrieved April 20, 2009, from https://acc.dau.mil/CommunityBrowser.aspx?id=44595

Defense Acquisition University (DAU). (2009b). *Operational mission scenario/mission profile (OMS/MP).* Retrieved April 24, 2009, from https://akss.dau.mil/askaprof-akss/qdetail2.aspx?cgiSubjectAreaID=14&cgiQuestionID=16649

Defense Science Board. (2008, May). *Report of the defense science board task force on developmental test and evaluation.* Washington, DC: Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics. Retrieved February 7, 2009, from http://www.acq.osd.mil/dsb/reports/2008-05-DTE.pdf

Defense Systems Management College. (1999, December). *Acquisition strategy guide* (4th ed.). Fort Belvoir, VA: Defense Systems Management College Press.

Department of Defense. (2005, August). *Guide to achieving reliability, maintainability, and availability.* Retrieved April 15, 2009, from https://acc.dau.mil/CommunityBrowser.aspx?id=31008

Department of Defense (DoD). (2008). *Defense Acquisition Guidebook.* Retrieved January 12, 2009, from http://akss.dau.mil/dag

DiMascio, J. (2004, September 13). DAB finalizing plan for staggered purchase of mobile gun system. *Inside.Defense.com*. Retrieved November 21, 2008, from http://www.insidedefense.com/secure/display.asp?docnum=ARMY-16-37-10&f=defense_2004.ask

DiMascio, J. (2004, October 11). Army officials to wrap up test plan before Stryker MGS memo signed. *Inside.Defense.com*. Retrieved November 22, 2008, from http://www.insidedefense.com/secure/display.asp?docnum=ARMY-16-41-3&f=defense_2002.ask

Dismascio, J. (2005, January 24). DOT&E reports safety, reliability concerns with two Stryker variants. *InsideDefense.com*. Retrieved November 22, 2008, from http://www.insidedefense.com/secure/display.asp?docnum=ARMY-17-3-5&f=defense_2002.ask

DiMascio, J. (2005, November 14). Krieg allows mobile gun system to move into low rate production. *Inside.Defense.com*. Retrieved November 21, 2008, from http://www.insidedefense.com/secure/display.asp?docnum=ARMY-17-45-9&f=defense_2002.ask

DiMascio, J. (2005, December 12). Army receives first two LRIP produced Stryker mobile gun systems. *Inside.Defense.com*. Retrieved November 21, 2008, from http://www.insidedefense.com/secure/display.asp?docnum=ARMY-17-50-10&f=defense_2002.ask

DoD news briefing: Secretary of Defense William J. Perry. (1995, December 8). Briefing. Retrieved February 24, 2009, from Defense Link website, http://www.defenselink.mil/transcripts/transcript.aspx?transcriptid=202

Fahey, K. (2008, October 24). *PEO GCS advance planning briefing to industry*. Briefing. Presented at the Advance Planning Briefing to Industry at the Tank and Automotive Command Life Cycle Management Center (TACOM LCMC). Retrieved February 15, 2009, from http://contracting.tacom.army.mil/FUTURE_BUYS/FY08/APBI%202008%20-%20Day%202/fahey.pdf

Federal News Service, Incorporated. (2000, November 17). *Army discusses interim armored vehicle (IAV) program.* Special Briefing. Presented by Army Lt. Gen. Paul J. Kern, Military Deputy Assistant Secretary of the Army for Acquisition, Logistics, and Technology at the contract award of the IAV. Retrieved December 1, 2008, from Defense Link website, http://www.defenselink.mil/transcripts/transcript.aspx?transcriptid=1858

Federation of American Scientists. (2000, January 31). *Draft medium armored vehicle (MAV) operational requirements document (ORD) Training and Doctrine Command (TRADOC).* Retrieved November 21, 2008, from http://www.fas.org/man/dod-101/sys/land/docs/bct/MAV-ORD-31-Jan-00.htm

Fuller, P. (2004a, November 17). *Stryker mobile gun system IPR to BG James Myles (CG of Army Test & Evaluation Command)*. Briefing. Presented to BG Myles by the PM SBCT, COL Fuller. Briefing sent to researcher from Kim McCormick, GDLS Product Manager MGS, in January 2009.

Fuller, P. (2004b, December 20). *Mobile gun system update: Path to 72*. Briefing. Briefing sent to researcher from Kim McCormick, GDLS Product Manager MGS, in January 2009.

Gamboa, A. (2001, April 9). *General accounting office (GAO) decision on UD LP protest of ICV and MGS award to GM/GDLS*. Retrieved December 12, 2008, from http://archive.gao.gov/legald425p10/a00952.pdf

Gansler, J.S. (2000, July). *Commercial item acquisitions: Considerations and lessons learned.* Retrieved April 2, 2009, from http://www.acq.osd.mil/dpap/Docs/cotsreport.pdf

General Dynamics Land Systems (GDLS). (2002, August 8). *Draft safety assessment report (SAR)*. Report prepared for the Army Tank and Automotive Command (TACOM). The report was sent to the researcher by Mr. Joseph Godell, Deputy PM MGS in December 2008.

General Dynamics Land Systems (GDLS). (2005a). *MGS systems integration presentation.* Briefing. Briefing sent to researcher from Kimberly McCormick, GDLS Product Manager MGS, on January 22, 2009.

General Dynamics Land Systems (GDLS). (2005b). *MGS overview*. Briefing. Briefing sent to researcher from Kimberly McCormick, GDLS Product Manager MGS, on January 22, 2009.

General Dynamics Land Systems (GDLS). (2005c). *Ammunition handling system presentation*. Briefing. Briefing sent to researcher from Kimberly McCormick, GDLS Product Manager MGS, on January 22, 2009.

General Dynamics Land Systems (GDLS). (2007, April). *MGS systems engineering process and production TDP status*. Briefing. Briefing sent to researcher from Kimberly McCormick, GDLS Product Manager MGS, on January 22, 2009.

General Dynamics Land Systems (GDLS). (2009). *MGS reliability growth chart (MEP)*. Original chart provided to researcher from Kimberly McCormick, GDLS Product Manager MGS, on January 22, 2009.

Gourley, S.R. (2003, May). Stryker's mobile gun system. *Army Magazine.* Retrieved December 12, 2008, from http://findarticles.com/p/articles/mi_qa3723/is_/ai_n9254703?tag=artBody;col1

Gutierrez, P.D. (2002, May-June). Commercial or non-developmental item acquisition strategy. *PM Magazine*. Retrieved February 10, 2009, from http://www.dau.mil/pubs/pm/pmpdf02/gut-mj2.pdf

Hillen, J. (2000). *Frontline: The future of war*. Public Broadcast System (PBS). Retrieved November 19, 2008, from http://www.pbs.org/wgbh/pages/frontline/shows/future/etc/synopsis.html

Hinton, H.L. (2001, May). *Army transformation faces weapon systems challenges.* Retrieved November 21, 2008, from http://www.gao.gov/new.items/d01311.pdf

Hobday, M. (1998). *Product complexity, innovation, and industrial organization*. UK: Complex Product Systems Innovation Centre. Retrieved January 20, 2009, from http://www.cops.ac.uk/

Hsu, E. (2002, July 22). Army accepts first pre-production mobile gun variant of the Stryker. *InsideDefense.com*. Retrieved November 21, 2008, from http://www.insidedefense.com/secure/display.asp?docnum=ARMY-14-30-12&f=defense_2002.ask

Hyunh, T. (2008, spring). *Systems analysis & system design evaluation and systems integration*. Unpublished presentation given to SE4011, Systems Engineering for Acquisition Managers. Monterey, CA: Naval Postgraduate School.

Iansiti, M. (1995). Technology integration: Managing technological evolution in a complex environment. *Research Policy, 24*(4). Retrieved January 12, 2009, from http://www.sciencedirect.com/science?_ob=PublicationURL&_tockey=%23TOC%235835%231995%23999759995%23156080%23FLP%23&_cdi=5835&_pubType=J&_auth=y&_acct=C000060280&_version=1&_urlVersion=0&_userid=3326500&md5=81c867bef9cf6d16d2110d654d757f43

Institute of Electrical and Electronics Engineers (IEEE). (1994). Standard for application and management of the systems engineering process. New York: Institute of Electrical and Electronics Engineers. Retrieved April 14, 2009, from http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=741941

International Council on Systems Engineering (INCOSE). (2006, June). *Systems engineering handbook: A guide for lifecycle processes and activities* (vers. 3). Seattle, WA: INCOSE.

Kauffman, S.A. (1993). *The origins of order*. New York: Oxford University Press.

Kern, P.J. (2000, May 22). *IAV source selection authority source selection plan, family of interim armored vehicles, Amendment #1.* Tank and Automotive Command (TACOM). TACOM publication sent to the researcher by Mr. Steve Dawson, PM SBCT, in February 2009.

Kratz, L.A. (2005, March 29). *Elimination of waivers to cite military specifications and standards in solicitations and contracts* (Policy Memo 05-3). Retrieved March 20, 2009, from http://www.dsp.dla.mil/app_uil/content/policy/docs/05-3.pdf

Light Armored Vehicles. (2008, August 13). BAE systems, ground systems M-8 armored gun system (AGS). Retrieved January 15, 2009, from http://jdet.janes.com.libproxy.nps.edu/JDIC/JDET/home.do

Maier, M.W., & Rechin, E. (2000). *The art of systems architecting* (2nd ed.). Boca Raton, FL: CRC Press.

McCarroll, S. (2008, March). *Stryker overview*. Briefing. Presented at the Stryker Buyer Bootcamp.

Millett, J., & Gillis, M. (1998, July-August). AMC confronts challenges, barriers to developing common sense, cost-effective performance specifications. *PM Magazine*. Retrieved February 1, 2009, from http://www.dau.mil/pubs/pm/pmpdf98/j-millet.pdf

Office of the Deputy Under Secretary of Defense (A&T). (2009, May). *Incorporating test and evaluation into Department of Defense acquisition contracts*. Washington, DC: Author. Retrieved May 25, 2009, from http://www.acq.osd.mil/sse/

Panel on Operational Test Design and Evaluation of the Interim Armored Vehicle. (2004). *Improved operational testing & evaluation*. Washington, DC: National Academies Press.

Pappalardo, J. (2008, March, 11). Stryker crews in Iraq rally to defend their rides: Field report, *Popular Mechanics magazine*. Retrieved April 15, 2009, from http://www.popularmechanics.com/technology/military_law/4253991.html

Pich, M.T., Loch, C.H., & De Meyer, A. (2002, March 11). On uncertainty, ambiguity, and complexity in project management. *Management Science, 48*(8). Retrieved April 15, 2009, from http://mansci.journal.informs.org/cgi/content/abstract/48/8/1008

Porter, M.E. (1996, November-December). What is strategy? *The Harvard Business Review, 74*(6).

Prencipe, A., Davies, A., & Hobday, M. (2005). *The business of systems integration*. Oxford, UK: The Oxford University Press.

Program Manager, Brigade Combat Team (PM SBCT). (2000, March 17). *Acquisition strategy report interim armored vehicle. Tank and Automotive Command (TACOM).* PM SBCT publication sent to the researcher by Mr. Steve Dawson, PM SBCT, in February 2009.

Program Manager, Stryker Brigade Combat Team (PM SBCT). (2006, March). *Stryker family of vehicles systems engineering plan (SEP).* PM SBCT publication used as part the Naval Postgraduate School Program Management and Controls class, Fall 2008.

Program Manager, Stryker Brigade Combat Team (PM SBCT). (2008, December). *Stryker acquisition strategy brief.* Briefing. Consolidation of several briefings sent to the researcher from Joseph Godell, Deputy Product Manager Mobile Gun System.

Project Management Institute (PMI). (2006). *The standard for program management*. Newton Square, PA: The Project Management Institute.

Repenning, N.P. (2001, March). Understanding fire fighting in new product development. *Journal of Product Innovation Management*. Retrieved February 2, 2009, from http://dspace.mit.edu/bitstream/handle/1721.1/3961/Tilting_v40-web.pdf?sequence=2

Roosevelt, A. (2004, August 11). Stryker mobile gun system preps for September DAB. *Defense Daily*, *223*(29).

Roosevelt, A. (2008, August 22). General dynamics moves ahead with Stryker MGS production. *Defense Daily*, *239*(38).

Rothwell, R.C. (1992). Successful industrial innovation: Critical factors for the 1990s. *R & D Management, 22*(3). Oxford, UK: Blackwell Publishing Limited.

Rush, H. (1997). Managing innovation in complex product systems. The Institution for Electrical Engineers. Retrieved February 2, 2009, from http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=00664051

Rykroft, R.W., & Kash, D.E. (1999). *The complexity challenge: Technological innovation for the 21st century*. New York: Pinter.

Schuster, C.R. (2002, May). *Army actions needed to enhance formation of future interim brigade combat teams*. Washington, DC: GAO. Retrieved November 21, 2008, from http://www.gao.gov/new.items/d02442.pdf

Senge, P.M. (2007). *The fifth discipline*. New York: Random House.

Shinseki, E.K. (2000, October). Army transformation. *Army Greenbook*.

Shinseki, E.K. (2001, March 1). Statement by the Chief of Staff of the United States Army before the Committee on Armed Services, United States Senate (SASC). Statement presented at the Second Session, 106th Congress on the Fiscal Year 2001 Budget and Posture of the United States Army. Retrieved December 1, 2008, from http://armed-services.senate.gov/statemnt/2000/000301es.pdf

Shinseki, E.K. (2003, June 11). Chief of staff farewell message. Retrieved December 1, 2008, from http://www.army.mil/features/ShinsekiFarewell/default.htm

Simon, H.A. (1976). *Administrative behavior*. New York, NY: Free Press.

Simon, H.A. (1978, May). Rationality as process and as product of thought. *The American Economic Review*. Retrieved March 15, 2009, from www.jstor.org/stable/1816653

Simon, H.A. (1979, September). Rational decision making in business organizations. *The American Economic Review*. Retrieved May 1, 2009, from http://www.jstor.org.libproxy.nps.edu/stable/pdfplus/1808698.pdf

Simon, H.A. (1981). *The sciences of the artificial*. Cambridge, MA: The MIT Press.

Steele, D. (2000, March). The Army stages a Kentucky demo to define the art of the possible. *Army Magazine, 50*(3).

Steves, M.R. (1997, Winter). Addressing risk management in non-developmental items acquisition programs. *Acquisition Review Quarterly*. Retrieved May 5, 2009, from http://www.dau.mil/pubs/arq/97arq/steve.pdf

Training and Doctrine Command (TRADOC). (2005, November 20). *FM 3-20.151, The mobile gun system platoon*. Retrieved April 10, 2009, from http://www.adtdl.army.mil/

Training and Doctrine Command (TRADOC). (2008, November 20). *Stryker capability development document (CDD)*. Document received from PM SBCT.

Tversky, A., & Kahneman, D. (1974, September 27). Judgment under uncertainty: Heuristics and bias. *Science*, 185(4157). Retrieved December 10, 2008, from http://web.me.com/fveltman/Course_Peking_University/Chapter_3_files/JudgementUncertainty.pdf

Under Secretary of Defense (AT&L). (2000, March). *Defense standardization policies and procedures* (DoD 4120.24-M). Washington, DC: Author. Retrieved February 1, 2009, from http://www.dtic.mil/whs/directives/corres/pdf/412024m.pdf

Under Secretary of Defense (AT&L). (2003a, May 12). *The defense acquisition system* (DoD Directive 5000.1). Washington, DC: Author.

Under Secretary of Defense (AT&L). (2003b, May 12). *The operation of the defense acquisition system* (DoD Instruction 5000.2). Washington, DC: Author.

Winograd, E.Q. (2002, November 25). Comptroller recommends filling mobile gun system funding gap. *InsideDefense.com*. Retrieved November 21, 2008, from http://www.insidedefense.com/secure/display.asp?docnum=ARMY-14-47-4&f=defense_2002.ask

Wynne, M.A. (2004, October 14). *Stryker acquisition defense memorandum (ADM)*. Memorandum from Defense Acquisition Executive to the Secretary of the Army.

Yin, R.K. (2003). *Case study research: Design and methods* (3rd ed). Thousand Oaks, CA: Sage Publications.

Yoder, E.C. (2004, November 1). *Engagement versus disengagement: How structural and commercially based regulatory changes have increased government risks in federal acquisitions* (Acquisition Research Working Paper Series). Monterey, CA: Naval Postgraduate School.

Young, J. (2007, July 30). *Configuration steering boards*. Memorandum from the Defense Acquisition Executive. Retrieved May 1, 2009, from https://acc.dau.mil/CommunityBrowser.aspx?id=160529

2003 - 2008 Sponsored Research Topics

Acquisition Management

- Acquiring Combat Capability via Public-Private Partnerships (PPPs)
- BCA: Contractor vs. Organic Growth
- Defense Industry Consolidation
- EU-US Defense Industrial Relationships
- Knowledge Value Added (KVA) + Real Options (RO) Applied to Shipyard Planning Processes
- Managing Services Supply Chain
- MOSA Contracting Implications
- Portfolio Optimization via KVA + RO
- Private Military Sector
- Software Requirements for OA
- Spiral Development
- Strategy for Defense Acquisition Research
- The Software, Hardware Asset Reuse Enterprise (SHARE) repository

Contract Management

- Commodity Sourcing Strategies
- Contracting Government Procurement Functions
- Contractors in 21st Century Combat Zone
- Joint Contingency Contracting
- Model for Optimizing Contingency Contracting Planning and Execution
- Navy Contract Writing Guide
- Past Performance in Source Selection
- Strategic Contingency Contracting
- Transforming DoD Contract Closeout
- USAF Energy Savings Performance Contracts
- USAF IT Commodity Council
- USMC Contingency Contracting

Financial Management

- Acquisitions via leasing: MPS case
- Budget Scoring
- Budgeting for Capabilities Based Planning
- Capital Budgeting for DoD
- Energy Saving Contracts/DoD Mobile Assets
- Financing DoD Budget via PPPs
- Lessons from Private Sector Capital Budgeting for DoD Acquisition Budgeting Reform
- PPPs and Government Financing
- ROI of Information Warfare Systems
- Special Termination Liability in MDAPs
- Strategic Sourcing
- Transaction Cost Economics (TCE) to Improve Cost Estimates

Human Resources

- Indefinite Reenlistment
- Individual Augmentation
- Learning Management Systems
- Moral Conduct Waivers and First-tem Attrition
- Retention
- The Navy’s Selective Reenlistment Bonus (SRB) Management System
- Tuition Assistance

Logistics Management

- Analysis of LAV Depot Maintenance
- Army LOG MOD
- ASDS Product Support Analysis
- Cold-chain Logistics
- Contractors Supporting Military Operations
- Diffusion/Variability on Vendor Performance Evaluation
- Evolutionary Acquisition
- Lean Six Sigma to Reduce Costs and Improve Readiness

- Naval Aviation Maintenance and Process Improvement (2)
- Optimizing CIWS Lifecycle Support (LCS)
- Outsourcing the Pearl Harbor MK-48 Intermediate Maintenance Activity
- Pallet Management System
- PBL (4)
- Privatization-NOSL/NAWCI
- RFID (6)
- Risk Analysis for Performance-based Logistics
- R-TOC Aegis Microwave Power Tubes
- Sense-and-Respond Logistics Network
- Strategic Sourcing

Program Management

- Building Collaborative Capacity
- Business Process Reengineering (BPR) for LCS Mission Module Acquisition
- Collaborative IT Tools Leveraging Competence
- Contractor vs. Organic Support
- Knowledge, Responsibilities and Decision Rights in MDAPs
- KVA Applied to Aegis and SSDS
- Managing the Service Supply Chain
- Measuring Uncertainty in Eared Value
- Organizational Modeling and Simulation
- Public-Private Partnership
- Terminating Your Own Program
- Utilizing Collaborative and Three-dimensional Imaging Technology

A complete listing and electronic copies of published research are available on our website: www.acquisitionresearch.org

THIS PAGE INTENTIONALLY LEFT BLANK

ACQUISITION RESEARCH PROGRAM
GRADUATE SCHOOL OF BUSINESS & PUBLIC POLICY
NAVAL POSTGRADUATE SCHOOL
555 DYER ROAD, INGERSOLL HALL
MONTEREY, CALIFORNIA 93943

www.acquisitionresearch.org