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Research Report

Understanding Why a Ground Combat Vehicle That Carries Nine Dismounts Is Important to the Army

Bruce J. Held, Mark A. Lorell, James T. Quinlivan, Chad C. Serena

RAND Arroyo Center/Force Development and Technology Program

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Preface

Following the termination of the U.S. Army's Future Combat System, the Army's desire to field an infantry fighting vehicle (IFV) that could carry a full nine-man infantry squad was, once again, in danger of not being met. Moreover, the operations in Iraq and Afghanistan during the first decade of the 21st century showed the vulnerability of legacy infantry vehicles to mines, rocket propelled grenades (RPGs), and, most significantly, improvised explosive devices (IEDs) in all their forms. Finally, the limitations on further developing the lethality, survivability, and network operations of legacy IFVs were becoming apparent. To address these issues, the Army initiated the current Ground Combat Vehicle (GCV) program.

This report explains how the Army's historical requirement for dismounted infantry squads is influencing the design of a new ground combat vehicle. The focus of the report, therefore, is on the question of why is it important to the Army that any new IFV be capable of carrying no fewer than nine soldiers who can be available for dismounted operations.

This research has been conducted in RAND Arroyo Center's Force Development and Technology program. RAND Arroyo Center, part of the RAND Corporation, is a federally funded research and development center sponsored by the United States Army. Questions and comments regarding this research are welcome and should be directed to the leader of the research team, Bruce Held, at held@rand.org.

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Summary

BLUF: The GCV is an Acquisition Program, but It's Really About Enabling Infantry Operations

- **Since absorbing the lessons of WW II and Korea, U.S. Infantry doctrine has emphasized fire and maneuver at the squad level**
  - **Fire and maneuver capability requires squads of 9 or more soldiers**
- **Future infantry operations will likely include more actions against technically enabled adversaries in complex terrain, requiring:**
  - **Protected and lethal mobility for the dismount squad elements, and;**
  - **An ability for the squad to conduct independent fire and maneuver <u>immediately</u> upon dismounting**
- **None of this is new:**
  - **The Army has been trying (for 50 years) to develop a survivable, lethal infantry fighting vehicle (IFV) that carries a 9-soldier squad**
  - **The Bradley IFV compromised squad size for vehicular lethality and cost savings**
- **GCV is about developing the IFV that enables both mounted <u>and</u> dismounted operations**

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Since the Army first started experimenting with mechanization[1] for its infantry units before World War II, it has endeavored to find the right mix of doctrine, organizations, and equipment to enable the most effective mounted and dismounted units. One lesson that has been consistent in practice and—as theorized in every Army schoolhouse—is that the most basic infantry unit capability is the capacity to maneuver dismounted while covered by suppressive fire. This tactic is fundamental at all echelons and defines the basic capability of the dismounted infantry squad. Partly because the Army's current infantry fighting vehicle, the M2 Bradley, cannot carry enough soldiers to enable squad-level fire and maneuver from a single vehicle, the Army has pursued development of the Ground Combat Vehicle (GCV).

At least some future Army operations are likely to occur in complex terrain that reduces the advantage that advanced sensors and long-range, precision munitions provide to U.S. military forces. These kinds of operational environments will require U.S. infantry forces to be equipped with protected and lethal mobility that allows closing with and engaging the enemy. Moreover, since mounted maneuver is often insufficient to defeat the enemy in complex terrain, infantry squads will require the capability to dismount and fight on foot. But dismounting in complex terrain will often occur under fire, when visibility and supporting fires between vehicles are more

[1] In this report, *mechanization* (or mechanized infantry) refers to the use of armored vehicles with off-road capability by infantry for both transportation and mounted combat. *Motorization* refers to the use of trucks or other unarmored vehicles to move infantry rapidly to where it is needed.

restricted and when communications between vehicles is difficult. Thus, unless squads are carried together in a single vehicle, they are more likely to be disadvantaged upon dismounting, particularly in unplanned situations—for example, when unexpectedly coming under fire or when attacked by an IED. If each squad is provided with a vehicle that can carry it, then the entire squad will be able to fire and maneuver much more rapidly upon exit from the vehicle.

The Army's statement of this requirement is not new. For over 50 years, it has tried to develop and field survivable, lethal IFVs that are capable of carrying a full infantry squad (numbering between nine and eleven men). That has been a challenge, and the Army's investment in the Bradley IFV compromised the capability to maintain a dismounted squad's fire-and-maneuver capability in favor of cost efficiency and the lethality provided by the TOW missile system.

The GCV is the Army's current attempt to address an issue it has identified for last six decades. If developed as planned, the GCV will provide the infantry with the IFV it has been trying to develop since the 1960s and, moreover, provide one that can grow and adapt to accommodate future requirements.

Acknowledgments

The study team wishes to express its appreciation to COL Robert (Rocky) Kmiecik and MAJ Eric Mendoza of the U.S. Army Maneuver Center of Excellence. Not only did they request this quick-turn look at the some of the issues that the GCV program is addressing, but their thoughtful comments improved our appreciation of the infantry's needs and, therefore, made this document better.

We would also like to thank our two reviewers, Dr. Bryan W. Hallmark of RAND and LTG James M. Dubik, U.S. Army (ret.). Their insightful comments improved the paper in both tone and content.

Abbreviations

AoE	Army of Excellence
APC	armored personnel carriers
AR	automatic rifleman
ASL	assistant squad leader
ASIRS	A Study of the Infantry Rifle Squad
BAR	Browning automatic rifle
BC/PL	Bradley Commander/Platoon Leader
BFV	Bradley Fighting Vehicle
BLUF	Bottom Line Up Front
BMP	Boyevaya Mashina Pekhoty (infantry fighting vehicle)
COIN	counterinsurgency
DIV 86	Division 86 study
FCS	Future Combat System
FIFV	Future Infantry Fighting Vehicle
GCV	ground combat vehicle
GPMG	general purpose machine gun
GREN	Grenadier
IED	improvised explosive device
IFV	infantry fighting vehicle
IRUS	Infantry Rifle Unit Study
LMG	light machine gun
MICV	mechanized infantry combat vehicle
NCO	noncommissioned officer
OCRSP	Optimum Composition of the Rifle Squad and Platoon
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
R	rifleman
ROAD	Reorganization Objective Army Division
ROCID	Reorganization of Current Infantry Division
RVN	Republic of Vietnam
SAW	squad automatic weapon
SL	squad leader
TL	team Leader
TOE	Table of Organization and Equipment

TOW	Tube-launched, Optically-tracked, Wire-guided
USMC	U.S. Marine Corps
WWI	World War One
WWII	World War Two

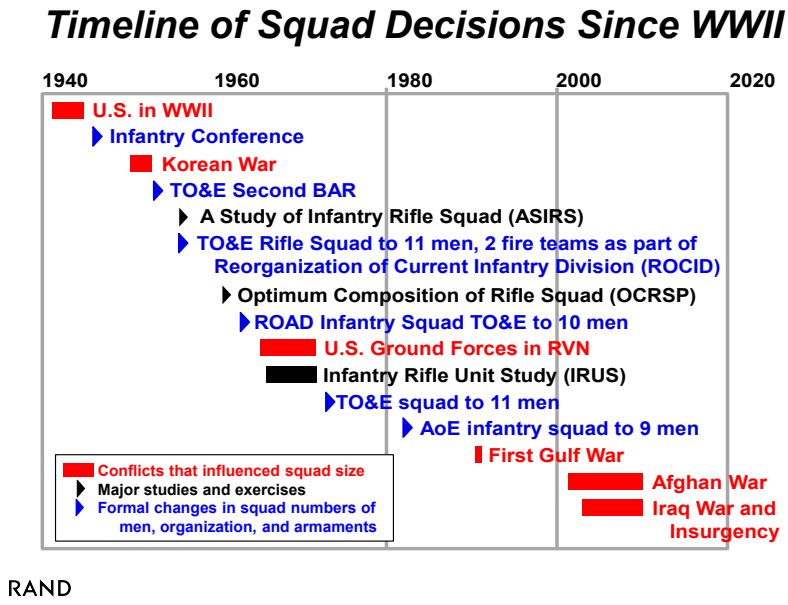
1. Introduction

Understanding Why a Ground Combat Vehicle That Carries Nine Dismounts Is Important to the Army

This report examines how the U.S. Army's mechanized infantry operations, tactics, and doctrine have dictated its requirement for an infantry fighting vehicle (IFV) that can carry at least nine dismountable soldiers. Since at least the Second World War (WWII), the U.S. Army has devoted substantial analytical effort to properly sizing and arming the infantry squad for optimal dismounted combat effectiveness, based on an ability to perform independent fire and maneuver tactics. The result of this analytic effort is a relatively consistent finding that the optimal squad size is nine to eleven soldiers. To support current infantry doctrine, the ability to carry a full dismountable squad has been and remains a key Army requirement for its new IFVs.[2]

[2] The Army did very little experimenting with mechanizing its infantry prior to 1940. There was a general recognition that motorization was useful, however, and by the mid-1930s some funding was available to purchase more trucks for this purpose (Mahon and Danysh, 1972). But the first vehicle really suited to mechanized infantry, the M3 halftrack, was not introduced into the Army until 1940.

2. Infantry Squad Size from World War II to the Present



The basic structure of the modern infantry squad began to emerge in 1946 and was formalized in Army doctrine in 1956. It remained essentially constant through several major conflicts, many important studies, and six formal changes in squad size and composition. In brief, that structure included squads made up of nine to eleven men (the preference being eleven), organized into two equally sized fire teams, aimed at optimizing the capability to independently carry out fire and maneuver tactics.

In this section, we review some of the key events and studies that led to the emergence, optimization, and retention of this squad structure throughout this long period, in spite of changing threats and weapons technologies. However, before we turn to the main historical events determining the size and composition of the squad after WWII, we examine the factors and metrics used to assess the capability and effectiveness of the squad.

Development of Rifle Squad Capability Has Focused on Leader Control, Fire-and-Maneuver, Lethality, and Resiliency

- **Reduced squad leader span of control requires help from an assistant or sub-unit leaders**
- **Elements subordinate to the squad are required for squad-level fire-and-maneuver**
  - **Fire teams provide that subordinate infantry element**
  - **Ad hoc subordinate elements have been used, though these are less effective than formally organized and trained fire teams**
- **Lethality is determined by the number of squad members and the mix and numbers of weapons**
- **Squad resiliency depends on sufficient numbers of soldiers for the squad to remain effective after loss(es)**

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The development of American infantry rifle squad capability has focused on four intertwined factors: (1) leader span of control, (2) the ability to conduct fire and maneuver at squad level, (3) lethality, and (4) resiliency. These four factors were part of most of the studies, and the trade-offs among those factors were often a focus of debate.

The first factor, leader span of control, refers to the number of people the infantry squad leader is required to directly control in the performance of an assigned mission. A reduced span of control allows the squad leader to focus more on his squad-level responsibilities and occurs when the squad leader has help from an assistant or sub-unit (fire team) leaders in controlling the individual soldiers of the squad.

Leader control thus translates into a squad leader's improved ability to control the squad in the performance of its primary and essential task: simultaneous fire and maneuver performed by subordinate elements of the squad.

Those subordinate elements typically consist of two fire teams. In fact, U.S. infantry squads are organized around the fire teams. That has not always been the case. Until the mid-1950s, other squad organizations were tried that did not include fire teams.[3] However, the increase in the lethality of the squad's weapons made squad-level fire and maneuver so essential that squad leaders created ad hoc subordinate squad elements to conduct it (Karcher, 2002, p. 25). But while ad hoc formations can and historically have been used for the performance of a range of

[3] For example, the WWII squad of 12 men consisted of a squad leader, an assistant squad leader, an automatic rifleman, an assistant automatic rifleman, ammunition bearer, two scouts, and five riflemen (Ney, 1965, p. 49). During WWI, the squad had been deemphasized and actually officially removed in doctrine in favor of the platoon and specialized "sections" to deal with the static warfare conditions of the Western Front (Ney, 1965, pp. 32–36).

missions, the squad is likely to be most effective when it is consistently trained to operate as it is organized.

In an addition to leader control, an infantry rifle squad's capability is also a function of its lethality. A squad's lethality can be measured by its capacity for massing firepower or other effects in pursuit of an objective. Firepower is a function not only of the *number* of weapons carried by the squad but also of the *types* of weapons that are organic or attached to the squad for the performance of a mission (antiarmor weapons, grenade launchers, automatic rifles, etc.). The lethality of the squad is also increased by the efficient and effective employment of these weapons insofar as they are used to support the squad's fire and maneuver.

The final factor contributing to the infantry rifle squad's capability is its resiliency. Resiliency is the squad's capacity to effectively conduct fire and maneuver even when the infantry rifle squad suffers attrition. Because the infantry squad is relatively small to begin with, the maximum loss it can sustain while still being able to fire and maneuver is also comparatively small. For example, depending on the mission being conducted, a nine-man infantry rifle squad that suffers a 33 percent loss may still be able to conduct fire and movement but would be unable to conduct fire and maneuver.[4]

[4] Hoffman argues that the dismounted element of a mechanized infantry squad becomes "dysfunctional" as an "integral" unit with as few as two losses, and at that point it must be combined with another squad. (Hoffman, 1990, p. 37).

An 11-Man Squad Has Been Preferred by the Army, but Was Hard to Retain

- **Army squad size and composition evolved to maximize capability while balancing force structure constraints***
  - **Infantry Conference (1946) – 9-soldier squad: SL, ASL, AR, 6xR**
    - **No fire teams, but retention of ASL allows limited fire & maneuver**
    - **Second AR replaced a rifleman during Korea**
  - **ASIRS Report (1956) – 11-soldier squad: SL, 2xTL, 2xAR, 6xR**
    - **Fire teams formally established to allow fire & maneuver**
  - **ROAD (1961) – 10-soldier squad: SL, 2xTL, 2xAR, 5xR**
    - **Personnel savings through asymmetric fire teams**
  - **IRUS Study (1969) – 11-soldier squad: SL, 2xTL, 2xAR, 6xR**
    - **Recommended a 9 soldier mech. Inf. squad, but not implemented**
  - **DIV 86 (1980) – 9-soldier mech. inf. squad: SL, 2xTL, 2xAR, 4xR**
    - **Light infantry squads retained 11 soldiers**
  - **AoE (1983) – 9-soldier squad: SL, 2xTL, 2xAR, 4xR**
    - **Initially standardized on 10 soldier squads, but savings were required**
    - **Current infantry squads retain this organization**
- **The Marines retain a 13-man squad with three fire teams**

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**There were many other studies, but those listed resulted in organization change*

The Army conducted or commissioned a number of major studies spanning the first five decades after World War II to examine the structuring, manning, and equipping of its infantry squads. These studies were compelled by a variety of factors, and their focus reflects broad changes in actual or projected operational environments, technology and weaponry, and operational concepts and doctrine.

The principal objective of each of these studies was to balance the capability provided by the infantry squad with standing operational and force structure requirements or directives. Although each study produced different findings based on the variables introduced, each also demonstrated a rather consistent requirement for maximizing squad effectiveness in terms of control, fire and maneuver, and lethality and resiliency. One finding that seemingly prevails irrespective of external factors is that a squad size of between nine and eleven men is required.[5] A brief summary of each of these studies is illustrative in this respect:[6]

- The Infantry Conference of 1946 found that despite not being organized around "fire teams," an infantry squad (consisting of twelve men) could conduct limited fire and maneuver with the addition of an assistant squad leader to help control the actions of the squad. The report also found that the infantry squad should consist of nine men in order to abet command and control and to offset possible attrition during combat.[7]

[5] Although the U.S. Marine Corps (USMC) differs from the Army in respect to the number of personnel it assigns to its infantry squads (13 as opposed to 9–11, respectively), it has also found that a 13-man squad balances its operational and force structure requirements. This has been the USMC standard infantry squad size since World War (WW) II.

[6] Fuller descriptions of these studies and their outcomes appears later in this section.

[7] See Melody, 1990, pp. 5–6. Many of these findings were confirmed during combat operations in Korea (Melody, p. 10). See also Karcher, 2002, p. 8.

- In light of experiences in the Korean War (and WWII), the Army conducted "A Research Study of the Infantry Rifle Squad" (ASIRS) and found that both the nine-man and eleven-man squad were effective when organized around the fire team concept but that the eleven-man squad allowed for the conduct of fire and maneuver simultaneously.[8] Accordingly, the Army adopted a squad composed of eleven men.[9]
- In preparation for the possibility—if not likelihood—of nuclear warfare and an increasing operational requirement for tactical mobility, the Army commissioned the Reorganization of the Army Division (ROAD) study in the early 1960s.[10] The study found that changes in weaponry leading to increased squad lethality would allow the Army to decrease the infantry squad's size by one man—to a total of ten men—through the use of unbalanced or asymmetric fire teams.[11]
- As a result of a study conducted between 1966 and 1972 titled "The Infantry Rifle Unit Study" (IRUS), the Army once again adopted the eleven-man infantry squad.[12] The study determined that the Army should return to an infantry squad manned by two balanced fire teams. It also recommended that mechanized infantry squads be reduced to nine men, although this recommendation was not adopted at that time.[13]
- In 1980, the Army began the Division 86 study (DIV 86) as a means of assessing ways to reduce the size of the Army's infantry divisions to reflect standardization and efficiency requirements. Like IRUS, DIV 86 recommended an eleven-man light infantry squad and a nine-man mechanized infantry squad. But unlike IRUS, DIV 86's recommendations were accepted and implemented in the early 1980s.[14]
- Finally, the standardized nine-man infantry squad familiar to all of today's Army infantry units is a product of a series of force structure and organizational changes recommended by the Army of Excellence (AoE) study of 1983. Although the Army had accepted that a ten-man infantry squad was ideal when the study was released, two key factors combined and led to the adoption of the nine-man squad: top-down force planning that made the squad the "bill-payer" for shrinking the size of the corps and division, and mechanized infantry doctrine and the introduction of the Bradley Fighting Vehicle (BFV).[15]

It is important to note that the standardization of the nine-man infantry squad resulting from the 1983 AoE study represented a compromise from doctrinal Army requirements. In this instance, force structure requirements were important enough to reduce squad size below what infantry doctrine would otherwise dictate. It is also important that while the nine-man light

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[8] Melody, 1990, p. 23.

[9] Melody, 1990, p. 24.

[10] See Ney, 1965, pp. 66–68.

[11] This was reflected in changes to Table of Organization and Equipment (TOE) 7–18 in 1964 (Ney, 1965, p. 66). See also Karcher, 2002, p. 9.

[12] Melody, p. 37.

[13] Karcher, p. 65.

[14] Karcher, p. 65.

[15] See discussion in Romjue, 1993, pp. 14, 49, 54, and 111. See also Karcher, 2002, pp. 68–69.

infantry squad could still conduct fire and maneuver, its mechanized counterpart could not. In effect, the nine-man mechanized infantry squad was divided into a three-man vehicle crew that did not dismount and a six-man dismounted infantry section. The six-man dismounted infantry section, which is often separated from its mounted counterparts during operations, is smaller than the thresholds identified in the earlier studies as being required for effectiveness in terms of either squad control, fire and maneuver capability, lethality, or resiliency. Only under some circumstances, such as when the vehicle can provide effective supporting fires, is the nine-man mechanized infantry squad capable of effectively conducting squad operations.

The remainder of this section reviews several of the most important studies (summarized above) to illustrate in more detail why the Army initially came to adopt the nine- to eleven-man squad organized into two fire teams, and how and why this structure and squad size persisted as the objective goal for six decades until the present period.

The 1946 Commanders Conference & the Foundations of the Modern Fire & Maneuver Squad

- **Dissatisfaction with the WWII 12–man, 3-element squad organization**
  - **Too complicated and unwieldy**
  - **Impressed with the German infantry squad organized around the MG42 light machine gun**
- **Infantry Conference convened in 1946 to review lessons of the war, examines squad**
  - **Removes 2-man scout element, one assault rifle**
  - **Recommends 9-man squad to enhance control**
- **Subsequent revisions move closer to the modern 2-fire team squad structure**

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The Early Post–World War II Quest for the Optimal Squad Size and Organization

For three years during World War II, elements of the U.S. Army conducted vast combat operations on a scale unseen since the Civil War in a multitude of theaters and environments. The extensive combat experience accumulated collectively by the Army during this period led to a growing desire to reform and improve many aspects of the Army, including squad doctrine, organization, and armaments, in order to reflect and incorporate lessons learned from the war. Therefore, at the conclusion of the war, the Army's leadership agreed to convene a series of commander conferences organized by branch to review the lessons learned from the war and incorporate those lessons into the future force structure and organization. The Infantry Conference took place at Fort Benning, Georgia, and the results were published in June 1946. One of the main topics examined was whether the size and organization of the infantry squad should be altered.

The WWII infantry squad had contained twelve men organized into three elements: a two-man Scout element, a three-man fire element (a soldier armed with a Browning automatic rifle [BAR], an assistant gunner, and an ammunition carrier), and a five-man rifle element, all commanded by a squad leader and assistant squad leader. The Infantry Conference majority report recommended a reduction in the squad's size by three men to improve span of control and thus increase controllability. The majority report also felt that nine men could absorb some losses without becoming ineffective but did not accept the need for fully autonomous fire and maneuver capability or the need for two formally organized fire teams.

A minority report, however, which gained nearly as many votes as the majority report, placed great emphasis on obtaining full fire and maneuver capability for the squad. It recommended squads of only seven men, but it grouped two squads under a single section headquarters. This organization in effect acted as a much larger squad with two identical fire teams, which provided full fire and maneuver capability. Strong interest in equipping the squads with light machine guns-like the German MG42-was also expressed, but no appropriate U.S. weapon existed.

The majority report recommended the nine-man squad, but this organization was soon changed to enhance fire and maneuver capability. While the recommended size of the squad remained unchanged, an assistant squad leader was reintroduced, providing an ad hoc capability to form two fire teams for fire and maneuver. By the beginning of the Korean War, this nine-man infantry squad had emerged as the basic Army squad organization.[16]

[16] This organization was, indeed, recognized as one that could be reformed to conduct ad hoc fire and maneuver (Dupree and Homesly, 1967).

Korean Experience Leads to Adjustment and Experimentation with the 9-Man Squad

- **Extensive Korean war combat leads to dissatisfaction with fire power of 1946 squad**
  - **9-man squad with one BAR was under-gunned**
  - **Ad hoc addition of second squad BAR allows "informal" organization of squad for fire and maneuver**
- **Continued quest for greater squad capability spurs numerous post-war "lessons-learned" studies**
  - **Much experimentation, but no formal changes**
  - **All indicated dissatisfaction with 1946 findings, interest in greater fire power, and enhanced fire and maneuver capability (i.e. larger squad)**

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The nine-man squad organization adopted from the majority report at the 1946 Commanders Conference centered upon the firepower of a light machine gun, but the U.S. Army lacked an adequate weapon of this type when it went to war in Korea. As a result, early experience in that conflict showed that the squad lacked firepower, and an additional BAR was provided to each squad (Hashim, 2000, p. 26). One result of this organizational development was a better capability for the squad to conduct independent fire and maneuver. Instead of an automatic rifle section laying a base of fire as the rest of the squad maneuvered, having two BARs in the squad allowed the squad to be organized into two sections that could either maneuver or lay a base of fire while the other section maneuvered (Karcher, 2002, p. 29). In the three years following the war, from 1953 through 1955, the Army conducted at least three major exercises and studies in an attempt to discern the optimal size and organization of the squad, based on the lessons of the war.[17] In addition, an extensive 1955 study published by MG J. C. Fry called *Assault Battle Drill* exercised considerable influence on the size and organization of the squad. This study advocated formally establishing separate teams as the basic structure of the squad.[18]

While none of these studies, exercises, or books led quickly to a formal change in doctrine or structure of the infantry squad, they did convince the Army's leadership that the Korean War experience should shape the future structure and organization of the squad. In essence, the

[17] Operation Falcon, 1953; Exercise Follow Me, 1954–55; and Operation Sagebrush, a huge joint exercise in 1955 that included up to 140,000 troops.

[18] By this time, S.L.A. Marshall had published *Commentary on Infantry Operations and Weapons Usage in Korea: Winter 1950–1951.* This study suggested organizing the squad into two sub-elements that could support each other's maneuver with a base of fire.

Korean War laid the groundwork on which “fire and maneuver” would become the fundamental doctrine of American infantry squads, while the organizational requirement to enable this doctrine would be a squad with at least two sub-elements, each able to provide fire support to the other. This was the basis for the requirement that American infantry fighting vehicles should be big enough to carry a full, nine-soldier squad.

ASIRS (1956): The Modern 2-Team Fire-and-Maneuver Infantry Squad Is Officially Born

- **1955-1961 sees birth of the modern infantry squad: an 11-man, 2-team squad focused on fire and maneuver**
- **Post-Korean War ferment comes to head in A Study of the Infantry Rifle Squad (ASIRS) in 1956**
  - **Formalizes design of squad into 2 fire teams of 5 men each**
  - **Teams built around automatic rifleman and team leader, plus 3 ordinary riflemen**
- **Changes formally implemented through "Reorganization of Current Infantry Division" (ROCID)**

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The Formal Emergence and Retention of the Modern Infantry Squad

The Army finally launched a major reassessment of the optimal size and organization of the squad in 1956. This study, entitled "A Research Study of Infantry Rifle Squad Table of Organization and Equipment (TOE)," or ASIRS, proved to be one of the most influential studies of the post–World War II era. It established in formal organization and doctrine the key trends that had been developing since the 1946 Commanders Conference regarding the evolution of the modern squad. ASIRS ultimately led to the formal selection of the eleven-man squad organized into two fire teams, each built around a team leader and a soldier with a high-rate-of-fire automatic weapon, plus three ordinary riflemen, as the optimal U.S. Army squad organization. This remained the official U.S. Army squad structure into the 1980s, and it persists as the Army's ideal objective squad structure up through the present day.

This structure was selected after careful analysis of multiple possible combinations of squad numbers and weapons. ASIRS ultimately concluded that the eleven-man squad with two equal fire teams, each with its own team leader and automatic weapon, provided the optimal balance of the sometimes conflicting goals of leader span of control, the autonomous ability to conduct fire and maneuver, lethality, and resiliency.

One of the most important elements of the ASIRS recommendations was the enlargement of the squad to eleven men to provide the critical minimally acceptable resiliency to preserve the squad's autonomous fire and maneuver capability, even after taking some casualties.

The ASIRS recommendations were formally implemented by the Reorganization of Current Infantry Division (ROCID) or Pentomic Reorganization of late 1956. This organization remained the official squad organization through the 1980s. In fact the eleven-man infantry squad size

persisted as the officially accepted norm until 1985, when it was reduced to a nine-man squad, largely due to cost considerations.[19]

[19] The DIV 86 study recommendation for a nine-man mechanized infantry squad was accepted in 1980. Even then, the eleven-man squad clearly remained the preferred objective goal.

Early Vietnam Era Sees Only Minor Adjustments to the 1956 ASIRS Standard Infantry Squad

- **Throughout the Vietnam War era the basic structure of the ASIRS squad was accepted & confirmed**
- **But studies under Reorganization Objective Army Division (ROAD) 1961-65 looked at new technologies**
  - **Optimum Composition of the Rifle Squad & Platoon (OCRSP) examined M60 GPMG for squad use**
  - **Confirmed the 11-man squad as optimal**
  - **Recommends M60 GPMG replace automatic rifle**
- **ROAD reduces squad size to 10 for budgetary reasons**

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In the 1960s the substantial and current combat experience being gained in Vietnam and the emergence of new weapons and technologies—such as an effective light machine gun (M60 general purpose machine gun or GPMG)—encouraged the Army to conduct new studies and exercises to determine whether the size and the organization of the squad should be changed. The most important of these studies was the Optimum Composition of the Rifle Squad and Platoon (OCRSP) study, conducted under the Reorganization Objective Army Division (ROAD) begun in 1961.

OCRSP examined a wide variety of configurations of different-sized squads equipped with different weapons, the most important of which were the M60 GPMG and rifles with grenade launchers, as well as the new M14 select-fire assault rifle. OCRSP found that, even when equipped with the new more-lethal weapons, squads still needed to be sized at between ten and twelve men to retain sufficient firepower for fire and maneuver tactics and, more importantly, to possess the resiliency to retain the capability to conduct fire and maneuver even after multiple casualties. Factoring in considerations of span of control as well as cost, OCRSP concluded that the optimal squad size was eleven men. Thus, a second major Army study confirmed the same recommended squad size and organization that had emerged from the study. The only major change recommended by OCRSP was the substitution of the M60 GPMG for the BAR in each of the squad's two fire teams.[20]

The larger umbrella ROAD study concentrated on the strategic rather than the tactical level. This study aimed at developing lighter, more deployable, less expensive Army divisions, which

[20] While the M60 provided greater firepower, it also required additional logistic support in terms of ammunition supply; required greater crew effort to service the weapon, thus removing crew members from other duties in the fire team; and limited their mobility and agility because of the greater bulk and weight of the weapon and ammunition.

could fight in a nuclear environment. In pursuit of these goals, the ROAD team accepted the OCRSP recommendations but reduced the number of infantrymen in the standard squad from eleven to ten. This change was justified primarily on the grounds that future technological developments in weaponry would increase the lethality of infantry units.

The Infantry School attempted to rebut this recommendation, insisting that eleven-man squads were necessary to retain sufficient firepower and resiliency to conduct fire and maneuver tactics, but it failed to win the argument against the perceived benefits of cost savings and improved deployability. The Infantry School also objected to the need for accepting asymmetric fire teams with a ten-man squad, but it lost this argument too.

Thus the reassessments of the first half of the 1960s resulted in relatively minor changes but ultimately confirmed the basic organization, size, and structure of the squad as it had been laid out in the 1956 ASIRS study. Indeed, extensive analysis of combat outcomes in Vietnam fully confirmed the OCRSP findings. Studies conducted for the Army by Booz-Allen and carried out in 1966–67, based on interviews with officers and noncommissioned officers (NCOs) with extensive Vietnam combat experience, confirmed widespread support among the warfighters for the squad organization and size mandated by the ASIRS and confirmed by the OCRSP studies.

Nonetheless, the ROAD study decision to eliminate one soldier from the eleven-man squad established a precedent of reducing squad size primarily for cost reasons in spite of operational objections and actual combat experience.

IRUS (1965-1972), Most Extensive Study Ever, Again Confirms ASIRS' 11-Man Squad

- **Infantry Rifle Unit Study (IRUS) confirms 11-man squad as optimal after extensive analysis**
  - **13-man squad considered superior, but expensive**
  - **11-man squad as minimum for sustainability & maintaining full fire & maneuver capability**
  - **Recommended for light infantry, airborne, airmobile**
- **In major departure, 9-man mech squad recommended**
  - **Assumes heavily armed IFV compensates**
  - **Army accepts 11-man squad, but not 9-man mechanized squad**
- **Army enters 1980s with same ASIRS 11-man squad**

RAND

As noted earlier, the Army Infantry School did not support the reduction of the infantry squad from eleven to ten soldiers, as recommended by the ROAD study. Consequently, the Army continued to experiment and analyze the combat data coming out of Vietnam to optimize squad size, organization, and weapons. The Booz Allen studies commissioned by the Army, conducted in 1966–67 and based on interviews with squad-level soldiers with combat experience,[21] found that the vast majority of interviewees preferred a squad with eleven or twelve men. Interviewees believed that fire and maneuver capability was not possible with a squad of fewer than seven or eight men, suggesting that resilience was a key reason to maintain a relatively large squad size. Because of these findings, the IRUS study selected thirteen-, eleven-, and ten-man squads as the main focus of its analysis.

IRUS determined that a thirteen-man squad was the most effective from the standpoint of firepower and resiliency, but concluded that it was not cost effective. However, IRUS also rejected the ten-man squad derived from the ROAD study as possessing insufficient resilience. IRUS also criticized the ROAD squad for its asymmetric fire teams (one five-man and one four-man team), which it concluded made fire and maneuver tactics more challenging. Consequently, IRUS recommended the eleven-man squad as optimal, confirming the findings of the 1956 ASIRS study.[22]

The IRUS study also endorsed a nine-man squad for mechanized infantry applications, as opposed to eleven-man squads for light infantry, airborne, and airmobile uses. This endorsement

[21] Williams and Homesley, 1965.

[22] However, the IRUS recommendation for squad use of the Stoner 63A machine gun was not accepted. Rather, the standard M16 automatic assault rifle on full automatic became the automatic weapon for each of the two five-man fire teams.

assumed that the gun on the IFV as well as the crew of the IFV would contribute significantly to the firepower and maneuverability of the mechanized platoon.

While the Army officially certified the IRUS recommendation for the basic eleven-man infantry squad, it did not act on the study's support for nine-man mechanized infantry squads mounted on IFVs. In 1973, however, the Army organized eleven-man squads mounted on M113 armored personnel carriers (APCs) armed with M2 50-caliber machine guns. Two of the soldiers in this configuration acted as the APC driver and machine gunner, leaving a nine-man infantry element to dismount. This element was equipped with an M60 GPMG to compensate in part for its smaller numbers. Thus the nine-man mechanized infantry squad recommended by IRUS was, in effect, informally accepted.[23] This change also provided a precedent for the later formal acceptance of the nine-man mechanized infantry squad that resulted some years later from the DIV 86 study.

[23] See Hughes, 1994.

Post-Vietnam Army 86 Study Leads to Major Force Structure Changes

- **Army 86 Study (1978-80) sought optimal organization & equipment for the post-Vietnam era**
  - **Broad threat spectrum: Soviet build-up, Iran hostage crisis, Afghan War**
  - **New technology: Anti-tank missile, Soviet BMP**
- **Army 86 goals ultimately focused on mixed capabilities**
  - **Strong Mech/Armor divisions for the European theater**
  - **Light divisions for strategic mobility**
- **Div 86 study conducted under Army 86**
  - **Accepts recommendations for 9-man mech squad**
  - **Personnel and cost constraints were key factors**
  - **Fire-power of IFV compensates for smaller squad**

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At the end of nearly ten years of major combat action in Southeast Asia, much of it focused on counterinsurgency operations, the Army paused to reassess its organization and force structure for the future. In 1979, following a series of smaller studies, such as the Division Restructuring Study, the Army launched a large-scale, top-down analytical strategic study called Army 86. This study aimed at assessing the optimal organization and equipment for the post-Vietnam era in an uncertain environment of multiple types of threats and an array of new weapons and technologies.

Initially the Army almost exclusively concentrated on the traditional European theater and the threat posed by a continuing buildup of armor-heavy Soviet and Warsaw Pact forces. But soon, the Iran hostage crisis beginning in November 1979 and the Soviet invasion of Afghanistan the following month redirected Army interest away from the Europe Central Region and toward worldwide contingency operations and rapid deployability.

At the same time, new technologies and weapon systems were spurring significant changes in doctrine and operational concepts. The Yom Kippur Arab-Israeli war in October 1973, for example, demonstrated the effectiveness of man-portable antitank missiles, and raised questions about the continued utility of massed armored concentrations used in blitzkrieg-style attacks that lacked organic mechanized infantry formations.

The lessons from the Yom Kippur War, combined with the growing Soviet armored threat and other factors, led the Army to place an increased emphasis on mechanized infantry formations. Perhaps most important, the Soviets publically revealed a new IFV in 1967, the BMP-1, underscoring the Army's failure to deploy a purpose-built IFV of its own. Such factors led to the initial plan in the 1970s to mechanize all infantry divisions and made the development and deployment of a true armored IFV more urgent. The Army wanted a vehicle like the BMP,

designed from its inception for the high-intensity armor environment, not a modification of an APC such as the M113.

Given this emphasis, the Army 86 study evaluated the mechanization of Army infantry divisions, each equipped with purpose-built IFVs. These divisions would support armored divisions and would act to counter the heavy concentration of Soviet armor present in the European theater. Following the Soviet invasion of Afghanistan and the shift in emphasis toward deployability and contingency operations, Army planners switched priorities to building a mixed force of heavy and light divisions to service the entire spectrum of threats and possible contingencies. This led to a redirection of studies toward evaluating lighter, more deployable contingency forces, equipped with considerable firepower capabilities.

The first element of the Army 86 effort was the Division 86 study component, launched in the fall of 1979, which initially examined new heavy division concepts. DIV 86 remained centered on higher-level formations, and therefore did not conduct a detailed analysis of squad numbers and composition. As a result, the eleven-man infantry squad dating back to IRUS was initially retained. However, a variety of factors, primarily personnel costs and emerging IFV design issues (discussed in the next section), led to the formal acceptance of a smaller nine-man mechanized infantry squad as originally recommended by IRUS. Additionally, it was assumed that the firepower of the IFV in development would be able to compensate for the smaller squad size by providing a significant base of fire to support the maneuver of the dismounted element of the squad.

Concluding Historical Observations: Consistent Requirement for 9–11-Man Squad

- **1985 Army of Excellence Study standardized all squads at 9 men, primarily for cost reasons**
- **1999 Force XXI study considered & rejected 7-man squad as not resilient or lethal enough**
- **Bottom line: For the last half century, Army studies have shown a consistent need for 9–11-solder squads organized into two fire teams:**
  - **Manageable span of control for the squad leader**
  - **Resilient even with some loss of personnel**
  - **Lethal and flexible mix of weapons**
  - **Able to conduct independent fire and maneuver**

RAND

The Enduring Size and Organization of the Modern Infantry Squad

In the 1980s and 1990s, two other major studies revisited the issue of squad size.[24] The first was the 1985 Army of Excellence (AoE) study. This study emerged out of the 1983 Army Commanders Conference, at which Army leadership raised concerns about the "hollowing out" of the Army force structure and the deployability of major Army formations. The AoE study led to the further development and refinement of the light infantry division. To save costs, achieve Army-wide standardization, and lighten divisions to make them more deployable, the AoE study led to the reduction of all Army squads to nine men, thus aligning all infantry squads with the downsized nine-man mechanized squad formalized under the auspices of the DIV 86 study.

In 1984, the Army began implementing the recommendations from the DIV 86 and AoE studies. While reduced in manpower, the basic squad organizational structure as developed back in 1956 by the ASIRS study was retained. The Army divided the squad into two equal four-man fire teams, each with its own team leader. The new M249 Squad Automatic Weapon (SAW) replaced the M16 as the automatic weapon for each fire team. With nearly three times the rate of fire of the M16, the greater capabilities of the SAW were seen as at least partially compensating for the reduction in squad manpower from eleven to nine.[25] Thus, the new SAW-equipped nine-man squads were designed to maintain the full capability to undertake fire and maneuver.[26]

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[24] See Hughes, 1994, and Institute of Land Warfare, 2011.

[25] The M249 SAW was later called the M249 light machine gun (LMG).

[26] The M203 grenade launcher had replaced the M79 by this time. The M203 combined an M16 rifle with a grenade launcher, which meant that the fire team did not give up a rifle in order to provide itself with organic indirect fire.

The Force XXI study, conducted in the late 1990s, aimed at determining the optimal size of Army units for taking advantage of net-centric warfare[27] and a variety of new sensors and technologies under consideration for Army use. While focusing mainly on strategic issues and higher echelons, Force XXI did assess the utility of adopting a smaller seven-man squad for mechanized infantry units. Ultimately, the analysis led to a rejection of the seven-man mechanized infantry squad because it lacked sufficient firepower and resiliency to remain effective in the conduct of fire and maneuver tactics. Force XXI recommended the retention of the nine-man squad for all Army formations, including mechanized infantry.[28]

By the turn of the century, more than five decades of Army studies and analysis, dating back to the 1946 Commanders Conference, consistently concluded that the infantry squad needed to have at least nine soldiers and that the squad should be organized into two fire teams. These studies—which used a combination of experience from several major wars, field experimentation, and simulation—were based on findings concerning the management of squad leader span of control, the maintenance of combat capability in the face of personnel losses (resiliency), maximum lethality with available weapons, and the ability to effectively conduct fire and maneuver at the squad level. That these results are robust is attested to by the fact that the basic organization and equipment of the dismounted infantry squad has generally persisted for half a century.[29] This may seem counterintuitive given the improvements in the equipment and the growing quality of the American infantryman; however, it seems that the constants of span of control, a doctrinal requirement for squad-level fire and maneuver, lethality, and resiliency continue to be persuasive.[30]

While new capabilities have been introduced that can help the squad leader observe and control his dismounted soldiers—night vision goggles, for example—the ability to communicate with every soldier in the squad, particularly in complex terrain and under fire, remains elusive. New communications equipment is being slowly introduced and much experimentation has occurred over the last decade. But for the most part, dismounted squad communications continue to rely on verbal commands and hand-arm signals. Moreover, it is not clear whether the average dismounted squad leader conducting a difficult operation in complex terrain could effectively control more than a few of the squad's soldiers, even if enabled by better intrasquad

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[27] Net-centric concepts have evolved as technical limitations have become better understood. Today, the Army talks about "net-enabled" formations.

[28] As will be noted later, this decision would continue the tactical problems that were being encountered as the Army integrated the BFV into its mechanized infantry formations.

[29] Today's squad with nine soldiers is smaller by two than the mid-50s squad but is otherwise remarkably similar. Each has two symmetric fire teams with an automatic weapon (BAR versus M249 LMG), two grenadiers (rifle grenades versus M320 grenade launcher), and riflemen (M1 versus M16).

[30] The Army has not conducted a comprehensive study of squad organization on the order of IRUS since that significant effort in the 1960s, so the comments that follow are based on the authors' knowledge of the Army and on interviews and discussions with soldiers and officers.

communications and better situational awareness. At best, this still needs to be determined through experimentation and perfected through training.

Today, fire and maneuver remains the foundation for squad-level tactics.[31] For mechanized infantry, there are many situations where the squad's vehicles can provide a base of fire for a maneuvering, dismounted squad element. However, there are also many situations where the squad will need to fight dismounted without the benefit of overwatch by the squad's vehicles, particularly in complex terrain. In these situations, either the dismounted squad will need to be capable of fire and maneuver or the Army will need to adjust its doctrine.

The infantry squad today is also much more lethal than it was in the 1950s or during the Vietnam War. Its weapons have longer range and each soldier is better protected with effective body armor. The squad may also be equipped with sensors that allow it to see farther, and it has greater access to more responsive nonorganic fires and sensing assets. Nevertheless, these advantages will often be countered by enemies who are also better equipped than their predecessors, and in complex terrain the tactical benefit brought by the advanced equipment may be mitigated by the close ranges of engagement and the surprise that cover affords the enemy. A dismounted squad's relative lethality will thus continue to require both a mix of weapons to provide the necessary effects and enough weapons to provide a decisive density of fire.

Finally, resiliency remains a simple calculation, even for today's well-equipped squad. A dismounted fire team with three or fewer soldiers lacks resiliency simply because such a small team cannot take a loss without becoming combat-ineffective.

Since before World War II, the Army's development of infantry vehicles has always been informed by how the vehicle's passengers will fight when dismounted. While the vehicle can provide additional firepower to the dismounted squad in many situations, there are other situations where this is difficult; specifically, situations where the enemy must be fought at close quarters or where the vehicle is vulnerable and/or cannot navigate particular terrain. In these instances, the dismounted squads may be required to fight without support from the vehicle and must therefore rely on standard dismounted infantry tactics (fire and maneuver) with the weapons that they are carrying. Hence, the Army has always required that its infantry vehicles be designed to carry an entire dismountable squad.

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[31] FM 3-21.8, *The Infantry Rifle Platoon and Squad* is the basic doctrinal manual for small infantry unit tactics. The very first sentence of the manual states: "The mission of the Infantry is to close with the enemy ***by means of fire and maneuver*** in order to destroy or capture him, or to repel his assault with fire, close combat, and counterattack." (emphasis added). Later, paragraph 3-73 describes "bounding overwatch" as the preferred squad movement technique when contact with the enemy is expected. For a squad, *bounding overwatch* is the fire and maneuver technique whereby one fire team provides a base of suppressive fire while the other fire team maneuvers forward.

3. Integrating Dismounted Infantry Capabilities with Combat Vehicles

The Army Consistently Developed Vehicles to Carry a Complete Squad Capable of Fire and Maneuver

- **Armored Personnel Carriers (M75, M59, M113, M1126) always accommodated 9 to 11 dismountable soldiers**
- **Infantry fighting vehicle development in the US also stressed the ability to carry a full squad**
  - **XM701 – MICV-65 test bed (mid-60s); 3 crew/9 dismounts**
  - **Marder (1971); a German IFV, rejected by the Army because it could not carry 9 dismounts**
  - **XM723 – MICV (early-70s); 2 crew/9 dismounts**
  - **XM2 Bradley (mid-70s); originally 3 crew/9 dismounts**
  - **FIFV (late-80s); The Heavy Forces Modernization effort included an IFV with 9 dismounts**
  - **XM1206 (2000s) – FCS; designed for 9 dismounts**
- **A decision (political and budgetary) to make the M2 turret common with M3 reduced M2 dismount capacity, resulting in a Bradley that had seats for 6-7 dismounts**

RAND

M59

XM701

XM723

XM1206

Since the M3 halftrack was developed and fielded just prior to WWII, armored personnel carriers (e.g., the M75, M59, M113, and M1126[32]), or APCs as they have come to be known, have been sized to carry a full-sized squad of nine or more soldiers, excluding the vehicle crew.

But at least since the late 1950s, the Army has also been examining concepts and developing prototypes for an IFV that could carry a full-sized squad. For example, the XM701 concept of the mid-1960s carried nine dismountable infantrymen and possessed a turreted 20mm cannon. The Army even evaluated and rejected a fielded German IFV, the Marder, because it did not carry a full-sized squad. Ultimately, the Mechanized Infantry Combat Vehicle 70 (MICV 70) design study, completed in early 1968, concluded that a twelve-man armored vehicle was the optimal solution. This recommendation was accepted in January 1968 and the Army launched a program for a proof-of-concept prototype of the twelve-man XM723 MICV prototype.[33]

In 1972, the Army finally began a formal acquisition program for a new IFV, which later evolved into the M2 Bradley Fighting Vehicle. The BFV became the first true U.S. Army production IFV designed from its inception to fight in the high-intensity European conflict

[32] The U.S. Army officially calls the M1126 Stryker an infantry carrier vehicle rather than an armored personnel carrier.

[33] See Haworth, 1999.

against Soviet armored forces. As originally conceived, the BFV was designed to carry a standard infantry squad size of eleven men. As in the case of the M113 designs and other earlier concepts, some squad members would remain with the vehicle, thus limiting the number of infantry available for dismount to nine. This was seen as acceptable given the enhanced lethality and firepower of the IFV. In addition, as far back as the early 1970s, the IRUS study had recommended acceptance of a nine-man mechanized squad. Thus, in principle, the dismounted infantry capability planned for the new IFV met the squad force level recommended by the earlier IRUS study.

Ultimately, as the Bradley design evolved, the resulting IFV carried only six dismountable soldiers in the passenger space and three nondismounting crew members.[34] The decision to make this change, however, was based more on budgetary and political considerations than on tactical considerations or historical precedence. Commonality with the Cavalry Fighting Vehicle—being developed in parallel—drove the budget considerations. Budget savings in the post-Vietnam Army were an important selling point with Congress. In addition, important members of Congress were enamored enough with the tube-launched, optically-tracked, wire-guided (TOW) missile that the Army decided to integrate that space-hungry weapon system into the Bradley design (Haworth, p. 79).[35] Prevailing operational concepts and supporting doctrine for mechanized or combined arms operations generally supported these decisions, but the result was that fire and maneuver by dismounted infantry squads became much more difficult to execute in mechanized infantry units.[36]

Importantly, the Army quickly recognized that the Bradley was not ideal as a dismounted infantry support vehicle. Shortly after the Bradley was fielded the Army began new IFV development. The Future Infantry Fighting Vehicle (FIFV) concept of the 1980s Armored Modernization effort was intended to carry nine dismountable infantrymen. More recently, the IFV that was part of the Future Combat Systems (FCS) program, the XM1206, would also have carried nine soldiers in the passenger compartment.

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[34] It was not until the development of the M2A2 ODS (the Operation Desert Storm Bradley) that bench seating was added to accommodate seven dismounts.

[35] The author cites a quote by GEN Donn Starry, TRADOC commander from 1977 to 1981, in which he notes, "We in TRADOC . . . decided to put the TOW on the MICV because we realized that if we did not put the TOW on the MICV, we would probably never have a MICV."

[36] Haworth, p. 80. This issue is discussed further in the Appendix.

Fielding the BFV Resulted in Squad Size and Composition Issues

- **Initially, the Bradley seated 9 soldiers (DIV 86 and AoE squad size), but with three vehicle crewmen, only 6 soldiers could dismount**
  - **Squad dismounted fire & maneuver was severely compromised**
  - **Later Bradley versions seat 10 soldiers (7 dismounts)**
- **The first reorganization of the Bradley platoon (1988) consolidated the dismount soldiers into 2 x 9-soldier squads**
  - **Squad-level fire and maneuver capability restored, but**
  - **Dismounted platoon-level capability reduced because of fewer squads**
- **F series TO&E (1998) returns to 3x9-soldier squads, but:**
  - **Breaks squads and fire teams across the platoon's Bradleys**
  - **Which forces tactical compromises during dismounting operations**

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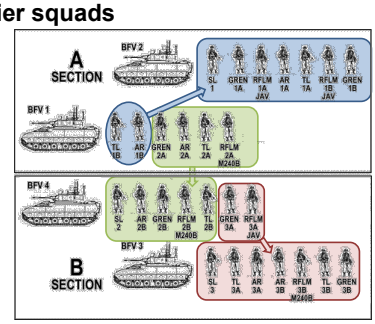

F-Series Bradley Squad Arrangement
Vehicle Crewman and Platoon HQ not shown

The Situation with the Bradley Fighting Vehicle

The fielding of the Bradley caused the Army to think and rethink mechanized infantry doctrine. This section of the report describes these efforts and the current situation.

The Army's decision to focus on the BFV's vehicular capabilities in mounted operations necessarily reduced the role and functionality of the infantry rifle squad in the conduct of dismounted operations.[37] An effect of this decision was the challenge to the infantry squad's nine- to eleven-man integrity. Although progressive changes to organization and doctrine occurred over the next few decades, many of these problems still persist today.[38]

Initially, and in line with the recommendations of the DIV 86 and AoE studies, the BFV seated nine soldiers total (the lower threshold for squad effectiveness). But not all nine of these soldiers could dismount the vehicle: Three had to remain with the vehicle as crewmen. This compromised the dismounted squad's effectiveness, particularly if the squad maneuvered without the benefit of covering fire from the Bradley. Although a squad leader could still control his dismounted element, those six-man elements could not conduct independent fire and maneuver, were less lethal, and were far less resilient as a unit. Even when later versions of the BFV allowed for seating seven dismounts, these same problems remained. Only when presented with the right circumstances—clear fields of fire and defilade positions for the vehicles—could the BFV infantrymen dismount and maneuver while covered by the Bradley's weapons.

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[37] Gibbons, 1995, pp. 24 and 33–34.

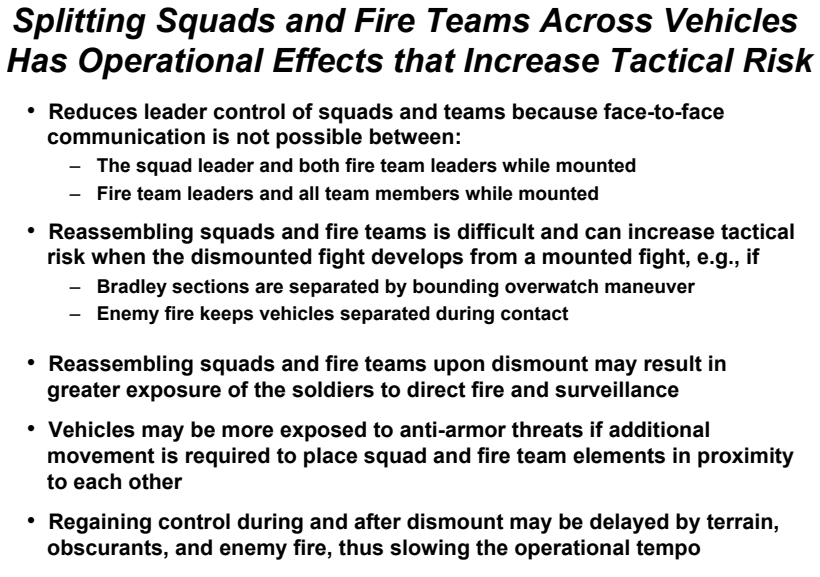
[38] Several studies discussed earlier in this report examined whether infantry squads in different types of units should be organized differently. Although some studies answered this question affirmatively, that is not the position of the Army today: "There are several variations of Infantry, but there is currently only one type of Infantry squad" (FM 3-21.8, para. 1–81).

The Army quickly recognized these problems and in 1988 authorized the first reorganization of the Bradley platoon. This reorganization led to a consolidation of the platoon's dismounted soldiers into two nine-man squads. Although the reorganization led to squads being broken apart for transport, the Army postulated that since the platoon's four BFVs fought as two sections and in relatively close proximity to one another, each of the nine-man squads could be quickly reconstituted by the squad leader upon the commencement of dismounted operations.[39] By restoring the integrity of the nine-man squad, the Army revived the mechanized infantry rifle squad's dismounted fire-and-maneuver capability.

But this came at a cost: While the squad was now more capable than previously, the mechanized infantry platoon was less capable than before because it now had only two squads available for the conduct of dismounted operations. To address this problem, the Infantry School at Fort Benning, Georgia, again reorganized the mechanized infantry platoon via the 1998 F-Series TOE changes. These changes brought about a return to three nine-man dismounting infantry squads capable of conducting fire and maneuver.[40] But like the changes that were issued a decade earlier, the F-Series TOE changes also posed problems to platoon effectiveness in general and squad effectiveness in particular. In order to transport three nine-man squads organized into two sections of two vehicles each, the platoon's infantry squads had to be broken apart and scattered among the platoon's four BFVs.

[39] See, Karcher, 73.

[40] "The good news is that the Infantry branch won a significant victory in the fight for structure within the Force XXI concept. With the loss of one rifle company in the Force XXI battalion organization, it was important to make sure the platoons in the remaining companies were capable of winning the close fight. Analysis showed that the four-vehicle platoon with three nine-man squads was best. Each of the three rifle squads in the Force XXI platoon has two balanced fire teams. . ." (Cucolo and Ringler, 1998, p. 7).



The Bradley platoon leader must consider several factors: (1) the rate of movement and the range of fire of mounted and dismounted infantry varies widely (48 kmph versus 3–5 kmph and 3,750m versus 1,000m, respectively);[41] (2) the BFV is best employed where long-range fields of fire are present, whereas dismounts are best employed where ranges and fields of fire are more restricted;[42] and (3) the range and power of adversary weapon systems necessitate that the platoon's BFVs remain separated during the mounted fight, but when the platoon transitions to the dismounted fight, the platoon leader and his subordinate squad leaders must ensure that the platoon's squads and fire teams are very quickly reassembled.[43]

With these factors in mind, the 1998 reorganization of the mechanized infantry platoon, which separated squads and fire teams for transportation purposes, affected squad operations. Squad leaders and some fire team leaders cannot directly communicate and control every member of their unit during and immediately after dismounting because the squads and fire teams are distributed across two vehicles; thus, face-to-face communication with both fire teams is not possible until the squad reassembles after leaving the vehicle. If dismounting is called for at a time when the tactical situation has resulted in the Bradleys being separated—for reasons of terrain, tactical movement techniques or enemy fire—reassembling the squads and fire teams may not even be immediately possible.[44]

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[41] Carmichael, 1988, p. 3.

[42] Carmichael, 1988, pp. 3–4.

[43] Karcher, 2002, pp. 73–74.

[44] The 2002 version of FM 3-21.71 recognizes the difficulties of dismounting and reassembling squads from different vehicles. It notes, "The fact that a single vehicle cannot deliver a rifle squad intact warrants the need for section drills." The description of the section drills is quite brief, but notably recognizes that 2nd Squad in particular may have difficulties reassembling: "If terrain separates the two platoon sections, the second squad's fire teams may

Particularly when dismounting is unplanned and occurs as a result of contact with the enemy, the soldiers of the squads and fire teams may be more exposed to enemy fire and surveillance immediately after dismount as they identify and rally to their leader. Likewise, if the vehicles need additional maneuver to gain proximity to one another for a dismounting drill, they may be exposed to additional enemy fire and surveillance.

This all suggests that the ability to conduct fire and maneuver immediately upon dismount is likely to be more difficult simply because the squad, and even the fire teams, need to reconsolidate from different vehicles. For the same reason, squad firepower is likely to be less coordinated while squad and fire team leaders are reestablishing control of their soldiers. And finally, squad resiliency is apt to suffer until the squad is reformed as a coherent whole.

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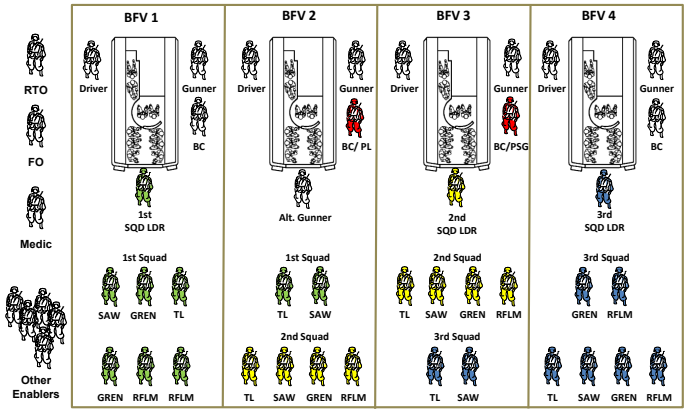
not be able to link up quickly. In this event, the fire team would provide M240B supporting fires for the maneuvering squad" (FM 3-21.71, Appendix A).

A BFV Platoon Leader is Forced to Make Other Hard Choices



A platoon must operate with squads below strength or without critical combat enablers

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The configuration problems posed by organizing the mechanized infantry platoon, squads, and fire teams around the BFV are not limited simply to the conduct of standard or doctrinal mechanized infantry missions with a full complement of soldiers. In fact, a platoon's assigned Bradleys have insufficient space to carry all the members of the platoon.[45] This space problem becomes more acute when the mission being conducted requires additional enabling personnel (e.g., organic platoon radio-telephone operators (RTO), medics, and forward observers (FO) or attached translators, civil affairs personnel, etc.).[46] Essentially, unless the platoon is reinforced with an additional vehicle, the platoon leader must decide how to reduce squad size, and hence effectiveness, to conduct anything other than the most basic mechanized infantry platoon or squad missions.

This is problematic when the platoon operates in comparatively less complex/more traditional operational environments. However, the problem is aggravated in more complex/irregular/unconventional operational environments where enablers are not a luxury but instead are a necessity for mission effectiveness. As operations have become more complex and as attached enablers have become more the norm than the outlier, the mechanized infantry rifle platoon and its subordinate squads and fire teams are challenged to organize doctrinally.

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[45] The current platoon organization includes 41 soldiers, but the four Bradleys have only 40 seats.

[46] ATTP 3-21.71 notes that in stability operations the infantry platoon may have a number of attachments, including human intelligence collection teams, linguists or interpreters, human terrain teams, weapons intelligence team, law enforcement personnel, explosive ordnance disposal personnel, tactical psychological operations teams, and combat camera crews.

The Greatest Operational Impact of Splitting Squads and Fire Teams Is on Squad Resiliency

- **Since the 50s Army infantry squads are organized in two fire teams to:**
  - **Reduce/improve squad leader span of control**
  - **Allow squad-level fire and maneuver**
- **But, combat experience indicates that fire teams of less than 4 soldiers lack resiliency**
  - **Surveyed Vietnam War combat leaders suggest that squads reduced to 7 or 8 soldiers must be organized as a single unit, so no squad-level fire and maneuver**
  - **Interviews with OIF/OEF veterans suggest that squad and fire team size is currently so small that a single casualty can postpone mission accomplishment due to casualty evacuation**
- **Resilient fire teams are necessary for a squad to retain fire and maneuver capability. A combat or administrative loss:**
  - **Can make the fire team combat ineffective**
  - **Eliminate important capabilities (LMG, marksman, grenadier)**
- **Combat, terrain issues, and leadership priorities for vehicle maneuver mean that fire teams split between vehicles are less likely to reform after dismount; making squads much less resilient and effective**

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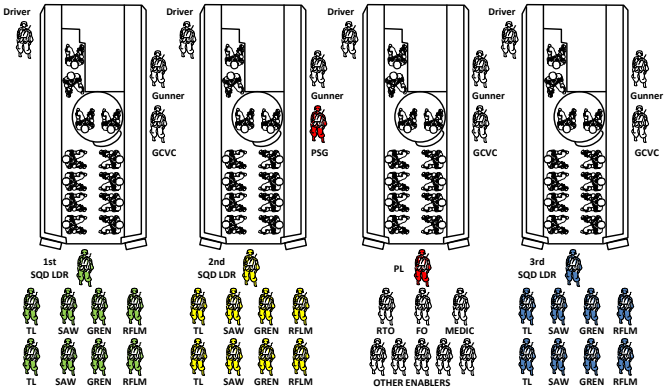
The bottom line effect of splitting squads and their fire teams—whether because of challenges presented by moving and maneuvering the squad in BFVs or because of the operationally requisite addition of various enablers—is reduced squad combat effectiveness, principally engendered by reduced squad resiliency.

Reducing the number of available mechanized infantry squad members causes two interrelated and cascading problems. First, each man on the squad has a specialty that is necessary for the squad to function properly. If one of these specialized soldiers is lost, a critical squad capability is also (usually) lost. Second, the squad requires a minimum number of personnel to conduct fire and maneuver. As discussed previously, it is not by historical accident that the Army has, since the 1950s, deliberately organized a nine-man, ten-man, or eleven-man squad into two fire teams: doing so enabled effective squad leader span of control and allowed squad-level fire and maneuver. Furthermore, having nine to eleven men integrated into the squad for training and operations ensured some level of innate resiliency. If a squad's fire teams are reduced to less than four soldiers, they become much less effective and require reconstitution or consolidation into another squad. Surveys conducted after the Vietnam War[47] and with returning veterans of Operations Iraqi Freedom and Enduring Freedom (OIF/OEF)[48] support these claims. In both conflicts, soldiers noted that the loss of one or two soldiers disallowed effective fire and maneuver and in some cases led to the postponement of mission accomplishment. Terrain issues and leadership priorities favoring mounted maneuver exacerbated these problems. In sum, circumstances or events that split a squad's fire teams or numerically reduce the squad's apportionment can lead to mission performance degradation or termination.

[47] Headquarters, U.S. Army, Military Assistance Advisory Group, 1964.

[48] The interviews were conducted as part of unpublished RAND research.

Replacing BFV on One-for-One Basis with GCV Eliminates the Operational Disadvantages of Split Squads and Fire Teams



And returns combat enablers to the platoon

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The Ground Combat Vehicle

While the Bradley Fighting Vehicle has provided good service to the Army and, more specifically, has enabled mechanized infantry to fight effectively as part of the combined arms, mounted maneuver team, it has essentially been a compromise solution for the infantry. The next section of this report describes how the GCV addresses the Bradley's compromises.

It is important to reiterate that even when the BFV was redesigned to seat seven soldiers and even after doctrine and TOEs were modified to support three nine-man mechanized infantry rifle squads in a mechanized infantry platoon, problems related to employing the platoon and its squads remained and were compounded by unfavorable changes in the operational environment. This latter problem resulted in platoons having to replace squad members with enablers for mission accomplishment. This difficulty principally stemmed from the fact that the BFV could not simultaneously carry the full platoon and mission-required enablers. As a result, the mechanized infantry platoon could also not simultaneously task organize for mission success and achieve squad effectiveness; all four factors determining squad effectiveness were reduced under these circumstances.

Replacing the BFV on a one-for-one basis by the GCV addresses these problems. This configuration of four GCVs per mechanized infantry platoon allows for the carrying of full nine-man squads (plus the three-man GCV crews) in a single vehicle. Three GCVs could therefore carry three complete mechanized infantry squads, and the fourth GCV can carry the platoon's organic and attached enablers.

4. Conclusion

GCV Must be Capable of Operating Seamlessly Across the Range of Military Operations

- **The Bradley IFV has performed well operationally, however:**
  - **Desert Storm and Phase 1 of OIF were primarily mounted maneuver fights with few opportunities for dismounted fire and maneuver**
  - **Early in the COIN phase of OIF, Bradley survivability compared very favorably with HMMWVs, which were often unarmored**
  - **As adversary tactics changed, the Bradley's limitations in survivability and squad organization became more apparent**
- **Over the potential 50 year life of the GCV, the US Army must be prepared for more challenging infantry operations, including:**
  - **Hybrid operations against competent enemies**
  - **Conventional operations against capable enemies in complex terrain**

  Such operations require a combination of survivability, lethality, and the ability to dismount an infantry squad that can conduct doctrinal dismounted operations

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Historically, the Bradley family of IFVs has performed well operationally. This is in part due to the fact that the Bradley was designed to fight and maneuver in support of tanks on a "mechanized army versus mechanized army" battlefield. Consequently, it performed well when subjected to the conditions for which it was designed. Operation DESERT STORM and Phase 1 of OIF provided proof of concept insofar as the BFV demonstrated that it could indeed be effectively employed in mounted fire and maneuver. It also performed well when used to support deliberate dismounted infantry operations. But in the later or COIN phases of OIF, some of the Bradley's weaknesses, particularly as a conveyance for the conduct of dismounted fire and maneuver, were exposed. Whereas the Army was previously accustomed to choosing the time and place it assembled its squads for the conduct of dismounted operations, thus controlling many of the variables affecting squad fire and maneuver capabilities, insurgent tactics in the later COIN phases of OIF, particularly with the increasing use of IEDs to initiate engagements, allowed the adversary more say in this regard. In these phases, threat forces—through the employment of complex ambushes—often were able to dictate when the mechanized infantry squad would dismount and thus the circumstances affecting the squad's ability to consolidate. In so doing, they exposed certain doctrinal and practical weaknesses inherent to using the BFV as a conveyance to support dismounted operations.

Unfortunately, at least in terms of the utility of the BFV, the Army can neither substantively change nor choose the operational environment within which it must perform its missions.

Rather, it must be prepared to function in complex and varying operational environments where the enemy has more control over the instantiation of conflict and where their use of technologically advanced platforms and weapons is the norm. These operational factors are likely to become even more challenging over the next five decades. For example, hybrid warfare operations of the type seen in southern Lebanon in 2006 where operations slide seamlessly between intense mounted combat and less intense, but deadly, security missions among a population, may become more the norm. Nor can the possibility of a fight against a more traditional, but more technically advanced adversary within the next several decades be dismissed. As a result of these possibilities, U.S. infantry fighting vehicles will need to be even more survivable than those currently fielded. Just as important, they will need to be able to transition seamlessly from mounted to dismounted operations, which means maintaining the squad's ability to conduct deliberate or extemporaneous dismounted operations immediately upon exiting their vehicle.

Since the 1950s, the Army's doctrine for dismounted infantry operations has stressed a squad organized around two fire teams and a squad size of at least nine soldiers. These doctrinal foundations have their basis in the concepts of squad-level leader control, fire and maneuver capability, lethality and resilience; concepts that have undergone continual review since the end of WWII. Recognizing this history of doctrinal development leads to understanding why the Army established a requirement that the GCV be able to carry at least nine dismountable soldiers. Lending further support to the Army's commitment to a nine-soldier squad, the Army has chosen to organize all infantry squads the same, even across different types of infantry units (light, mechanized, airborne). Importantly, the introduction of the Bradley Fighting Vehicle forced the Army to experiment with different squad organizations for mechanized infantry.[49] However, with the F-series TOE for mechanized infantry units, the Army came full circle and today's mechanized infantry platoon has three dismountable squads of nine soldiers each, who are organized into two fire teams per squad. This return came despite the tactical difficulties involved in the transition to dismounted combat in Bradley-equipped units. For the Army, the GCV therefore represents more than just an evolution of the IFV concept. It is an opportunity to fully integrate the concept of an IFV with the fundamental dismounted infantry doctrine that has evolved for over half a century.

[49] These included three nine-soldier squads in three of the platoon's Bradleys (three vehicle crewman and six dismounts) and two nine-solider dismountable squads with a fire team in each of the platoon's four vehicles.

Incompatible Requirements Made it Difficult to Combine Lethality, Survivability and Squad Capacity in One Vehicle

Stryker

Bradley

Stryker		Bradley
Provide infantry with protected mobility prior to their dismounting for the fight; machine gun support available when required	Purpose	Provide mobile fire power for the mounted maneuver fight; ability to dismount infantry when required
Machine guns or grenade launchers	Armament	25 mm cannon and TOW (Bradley) - 25 mm cannon and AT missile** - A majority of IFVs in service today have cannons of 30+ mm caliber
1.5 tonnes/soldier carried (Stryker) - 1.2 tonnes/soldier carried*	Protection	3.2 tonnes/soldier carried (Bradley) - 2.0 tonnes/soldier carried**
2 crew, 9 dismounts (Stryker) - 2 crew, 10 dismounts*	Personnel Capacity	3 crew, 7 dismounts (Bradley) - 3 crew, 7 dismounts**

*Average of APCs since 1960, excluding those based on tank chassis

**Average of IFVs since 1960

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At the time of the BFV's development, combined arms operations concepts—in particular, AirLand Battle—emphasized schemes of mechanized maneuver where the tank held primacy and other mechanized forces played a supporting role. This doctrine was designed with the IFV's mobility, lethality, and survivability in mind. Consequently, the BFV was thought of more as a vehicle that would operate in support of tank forces—moving and maneuvering at relatively similar speeds and distances—and only secondarily in support of or in combination with dismounted infantry, which operate at much slower speeds and cover ground much more slowly. Problems associated with training and employing a six-man (or even seven-man) dismount squad, either for its fire and maneuver function or as part of a combined arms team, were either not recognized or were subordinated to the BFV's mounted role during supporting tank operations.[50] While the support provided to dismounted infantry by a heavily armed fighting vehicle does provide some justification for weakening the dismounted squad's independent fire and maneuver capability—the vehicle provides covering fire while the dismounted soldiers maneuver—this comes at the cost of reducing the dismounted infantry's inherent flexibility, particularly in complex terrain. In such situations, such as fighting in urban areas, the vehicle

[50] Secondary issues, such as the inability of the six-man squad to operate as anything other than a single team and perform representative squad tasks, or the capacity of a six-man squad to function after suffering even minimal attrition, are discussed at length in Esper, 1990, and Carmichael, 1988.

may not be able to provide effective fire support to maneuvering dismounted soldiers, so the problems associated with squads that are too small become more evident.[51]

APC doctrine, on the other hand, is designed less to support the mounted maneuver fight. Rather, APCs are meant to carry infantry squads relatively close to where they are needed as dismounted fighters while providing some protection from indirect fire and direct small arms fire during the movement. To incorporate a passenger compartment large enough for nine to eleven dismounts, the APC has typically traded off mobility, armor, and large weapons.

In essence, the U.S. Army has, to date, been unable to field a vehicle that combines the passenger capacity of the APC with the lethality, survivability, and mobility of the IFV. However, the Army's struggle to develop effective dismount tactics for Bradley units continues to reinforce the need for such a vehicle.[52]

[51] It is worth noting that at the time the Bradley was developed, complex terrain was considered "no go" terrain for tank/IFV equipped mounted maneuver units.

[52] As noted earlier, after the Bradley was fielded, the Army attempted twice—first in the 80s with the Future Infantry Fighting Vehicle program; then in the 2000s with the Future Combat System—to develop an IFV that could carry a full dismountable squad. The development of the GCV continues these efforts.

Bibliography

Carmichael, John M., "Devising Doctrine for the Bradley Fighting Vehicle Platoon Dismount Element—Finding the Right Starting Point," Fort Leavenworth, Kan.: Command and General Staff College, 1988.

Cucolo, Anthony A., and Dale S. Ringler, "Heavy Infantry; Let's Revive Its Lethality," *Infantry*, September–December 1998, pp. 7–10.

Dupree, Robert, and Horace Homesly Jr., *A History of the United States Army: Squads and Platoons, 1935–1967,* Fort Benning, Ga.: Combat Developments Command Infantry Agency, 1967.

Esper, Michael H., "Dismounted Mechanized Infantry on the Future Airland Battlefield: Is the Squad Big Enough?" Fort Leavenworth, Kan.: U.S. Army Command and General Staff College, 1990.

Fry, James C., *Assault Battle Drill*, Harrisburg, Penn.: The Military Service Publishing Co., 1955.

Gibbons, Edward G., "Why Johnny Can't Dismount: The Decline of America's Mechanized Infantry Force," Fort Leavenworth, Kan.: U.S. Army Command and General Staff College, 1995.

Hashim, Ahmed, "Development of the Squad: Historical Analysis," Alexandria, Va.: Center for Naval Analysis, 2000.

Haworth, W. Blair Jr., *The Bradley and How It Got That Way: Technology, Institutions, and the Problem of Mechanized Infantry in the United States Army*, Westport, Conn.: Greenwood Press, 1999.

Headquarters, U.S. Army, *Mechanized Infantry Platoon and Squad (Bradley),* Field Manual 3-21.71, August 2002.

———, *The Infantry Rifle Platoon and Squad*, Field Manual 3-21.8, March 2007.

———, *Mechanized Infantry Platoon and Squad (Bradley)*, Army Tactics, Techniques, and Procedures, ATTP 3-21.71, November 2010.

———, Military Assistance Advisory Group, "Lessons Learned Number 36—Fire and Maneuver," San Francisco, Calif.: MAAG, February 4, 1964.

Hoffman, Hugh F.T., "Making the Most of What We Have—Combat Power and the Bradley Dismounted Infantryman," Fort Leavenworth, Kan.: U.S. Army Command and General Staff College, 1990.

Hughes, Stephen E, "The Evolution of the U.S. Army Infantry Squad: Where Do We Go From Here?" Ft. Leavenworth, Kan.: U.S. Army Command and Staff College, 1994.

Institute of Land Warfare, *The U.S. Army Squad: Foundation of the Decisive Force*, Arlington, Va.: Association of the United States Army, October 2011.

Karcher, Timothy M., "Enhancing Combat Effectiveness: The Evolution of the United States Army Infantry Rifle Squad Since the End of World War II," Fort Leavenworth, Kan.: U.S. Army Command and General Staff College, thesis, 2002.

Kempinski, Bernard, and Christopher Murphy, "Technical Challenges of the U.S. Army's Ground Combat Vehicle Program," Washington, D.C.: Congressional Budget Office, Working Paper 2012-15, 2012.

Melody, Paul E., "The Infantry Rifle Squad: Size Is Not the Only Problem," Fort Leavenworth, Kan.: U.S. Army Command and General Staff College, thesis, 1990.

Mahon, John K., and Romana Danysh, *Army Lineage Series: Infantry, Part I: Regular Army*, Washington, D.C.: Office of the Chief of Military History, United States Army, 1972.

Marshall, Samuel L.A., *Commentary on Infantry Operations and Weapons Usage In Korea: Winter 1950–1951*, Chevy Chase, Md.: The John Hopkins University, 1951.

Ney, Virgil, *Organization and Equipment of the Infantry Rifle Squad: From Valley Forge to ROAD*, Boston: Technical Operations, Inc., 1965.

Romjue, John L., "The Army of Excellence: The Development of the 1980's Army," Fort Monroe, Va.: U.S. Army Training and Doctrine Command, monograph, ORG Memorandum, CORG-M-194, 1993.

Williams, T. A., and Horace E. Homesley Jr., *Small Unit Combat Experience, Vietnam 1966–1967: Final Report*, Bethesda, Md.: Booz-Allen Applied Research Incorporated, 1967.