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THEATER MISSILE DEFENSE IN WORLD WAR II - SOME OPERATIONAL ART CONSIDERATIONS

by

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A paper submitted to the Faculty of the Naval War College in partial satisfaction of the requirements of the Department of Joint Military Operations.

The contents of this paper reflect my own personal views and are not necessarily endorsed by the Naval War College or the Department of the Navy.

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Theater missiles will remain a desirable weapon system from an enemy's perspective. Unlike World War II, modern conflicts are likely to be short and both sides will essentially "come as they are." Improvements in theater missile capabilities, coupled with their wider proliferation, will challenge the operational commander even more than before. At the same time, coalition partners and host nations will continue to place additional demands on the operational commander. Nevertheless, improving TMD capabilities will help the operational commander counter the threat. The continued development of TMD doctrine, coupled with improving capabilities and realistic training, should permit an effective TMD response in future conflicts.

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Abstract of

THEATER MISSILE DEFENSE IN WORLD WAR II - SOME OPERATIONAL ART CONSIDERATIONS

The World War II V-1 and V-2 attacks by Germany were the first effective use of theater missiles, and the first instance of a requirement for theater missile defense (TMD). The Allied response to German cruise (V-1) and ballistic (V-2) missile attacks incorporated all the elements of modern TMD concepts--Active Defense; Passive Defense; Attack Operations; and Command, Control, Communications, Computers, and Intelligence (C4I)--with varying success. Examining this historical case from the perspective of the three basic operational art factors--Space, Time, and Force--and their interrelationships provides some considerations for the operational commander planning and conducting TMD today.

Theater missiles will remain a desirable weapon system from an enemy's perspective. Unlike the Second World War, modern conflicts are likely to be short and both sides will essentially "come as they are." The various improvements in theater missile capabilities, coupled with their wider proliferation, will challenge the operational commander even more than before. Nevertheless, improving TMD capabilities will help the operational commander counter the threat. At the same time, coalition partners and host nations will continue to place additional demands on the operational commander. The continued development of TMD doctrine, coupled with improving capabilities and realistic training, should permit an effective TMD response in future conflicts.

1. INTRODUCTION

The situation the Allies faced late in World War II during the German V-1 and V-2 missile attacks is analogous to that a modern-day operational commander is likely to face. Germany was conducting ballistic (V-2) and cruise (V-1) missile attacks against Britain and Belgium. In response, Britain used a variety of means to actively defend against the V-1 missiles, and the Allies conducted strategic bombing against V-1 and V-2 launch sites and infrastructure. Today's operational commander may have to defend against similar missile attacks, and will likely possess some means to degrade or eliminate the enemy's missile capability. In light of this, there may be operational level lessons to be drawn from that war to help prepare for future conflicts requiring Theater Missile Defense (TMD).

2. CURRENT TMD CONCEPTS

To appreciate the relevance of any insights gleaned from the historical case, and to provide a common terminology, briefly reviewing current TMD operational concepts is useful. TMD is commonly separated into three elements--Active Defense, Passive Defense, and Attack Operations--all supported by a foundation of effective Command, Control, Communications, Computers, and Intelligence (C4I).[1]

Active Defense consists of those steps taken to engage and destroy a missile after it is in flight. This requires rapid detection, identification, targeting, and engagement by weapon systems such as the Army Patriot or Navy AEGIS-capable ships. The goal of Active Defense is to engage the "arrow" after the "archer" launches it.

Passive Defense consists of those measures taken to protect the target area from missile impact. It can include hardening, dispersion, camouflage, deception, shelters, and efforts to protect personnel and equipment from attack by Weapons of Mass Destruction (WMD). Effective Passive Defense is enhanced by timely warning of the attack.

Attack Operations are those steps taken to attack the "archer," optimally before he can launch his "arrow." These efforts can range from reactive "SCUD-hunting" of mobile missile launchers to preemptive attacks against supporting infrastructure. In the past, Attack Operations have relied heavily, though not completely, on air power.

None of these TMD elements can be successful in isolation. All three elements must be fully integrated for TMD to be effective. C4I is the key to effective coordination and integration of TMD systems and functions. The quality, quantity, and type of C4I required varies with the nature of the operation.

3. THE BASIC OPERATIONAL ART FACTORS[2]

To ensure a common foundation for this analysis, a brief review of the three most basic operational art factors--Space, Time, and Force--is in order before examining those factors and, more importantly, their interrelationships in the historical context.

a. Space - The size, shape, volume, and physical characteristics of the land, air, or water space significantly affect the employment of forces of both sides. Geo-strategic positions can be a benefit or hindrance. The dynamics and effects of gaining or losing space can affect operations. However, "the significance of the factor of space...cannot be

overstated...but [its] significance...should not be stressed too much, because its overall effect depends on the factors of 'time' and 'forces'."[3]

b. Time - "Time is one of the most precious commodities in the conduct of warfare, and is closely related to the factor of space, for time is needed to overcome the factor of space. Time lost can never be recovered."[4] Time is required to plan, prepare, conduct, and sustain military operations. A key to success is a sound understanding of the expected duration of the military operation. Disadvantages of space and inferiority in forces can sometimes be remedied by acting faster.

c. Force - The "means" to accomplish the objective, Force consists of both the combat forces and their logistical support. In contrast to the factors of Space and Time, the factor of Force can be difficult to quantify, especially at the operational level, because of its many intangible aspects (e.g., will to fight, public support, leadership, and doctrine). Numerical inferiority can often be offset by technological superiority or higher morale and discipline.

4. HISTORICAL OVERVIEW - SPACE, TIME, FORCE

In June 1944, Hitler initiated V-1 attacks against England. The V-1 was a pulse-jet-powered flying bomb with a 2,000-lb warhead and a maximum range of about 160 miles. Launched from a ramp, the missile flew a preset trajectory to a desired distance and then dove on whatever lay below. Germany launched 10,492 V-1s against England over

the next nine months, 7,488 reached England, and 2,420 hit London. Between June and September 1944, when London was the main target, V-1 raids caused nearly 6,000 casualties.[5]

Less than three months after the V-1 campaign began, the first V-2 attack occurred. The V-2 was a finned, gyroscopically-steered rocket with a 2,000-lb warhead and a range of about 2,000 miles. Its supersonic velocity enabled it to reach London just over five minutes after launch. Between the first attack in September 1944 and the final launch in March 1945, approximately 1,300 V-2s were fired against London. Of those, 517 reached their target, resulting in 2,511 deaths and 5,869 wounded.[6]

Germany also attacked Antwerp, Belgium from October 1944 to March 1945 in an effort to hamper Allied use of the city's port facilities. Over 5,600 V-1s and 1,440 V-2s reportedly hit in and around the city, but only slightly delayed logistics operations there.[7]

Allied efforts to counter the V-1 and V-2 took several forms. The V-1 could be intercepted by radar-cued fighters and targeted by antiaircraft fire. Barrage balloons over London also accounted for a small percentage of the V-1s brought down. Overall, British defenses brought down 53% of all V-1s observed; many of those never reached the English coast.[8] The Allies had no Active Defense against the V-2 because they could not detect the missile's launch or flight.

The Allied bombing campaign against the V-1 and V-2, dubbed Operation Crossbow, began even before the missile attacks themselves started. The first target was Peenemunde, a principal R&D facility, in August 1943. Allied bombing continued with attacks against production plants, identifiable launch facilities, and storage depots. Bombing efforts lasted until March 1945 and totaled almost 69,000 sorties flown and

about 122,000 tons of bombs.[9] Although Allied efforts hampered the German program to a limited degree, the V-1 and V-2 attacks continued intermittently until Allied ground forces overran the launch sites after D-Day.

5. OPERATIONAL ART FACTORS, RELATIONSHIPS, AND RELEVANCE

The preceding overview of the basic historical situation introduces the three basic operational art factors in a historical context. Although these basic factors alone are of interest, their mutual relationships are perhaps of more significance. Therefore, a more detailed examination of all three factors and their relationships in both historical and modern TMD contexts should result in lessons for the today's operational commander.

a. SPACE

As was mentioned, the V-1 and V-2 attacks originated in France and the Netherlands and were directed first at England and then also at Antwerp. The distances involved were relatively short--about 150 miles--especially from today's airpower perspective, with the English Channel seeming to provide an effective physical barrier between England and the rest of Europe.

However, considering the relationship between this Space and the Force involved in a TMD context causes the Channel to appear differently. From the German perspective, the Channel had little impact on V weapon use. In fact, the Channel helped protect those weapons from the Allies and forced the Allies to use airpower to attack

them. However, the Channel also helped Allied TMD efforts by providing a "kill zone" where the V-1s, at least, could be more easily engaged and with less risk to the English populace. This situation provides an excellent example of how the basic operational art factors can interact.

Indeed, from a TMD viewpoint, this Space-Force relationship is one that has not changed today. It remains one of the principal motivations for using such weapons--attacks can be launched from relative security geographically and from great distances. The operational commander must recognize this relationship, especially at a conflict's start when forces may not be fully committed in theater and when defenses are not in place to conduct TMD.

b. TIME

At the operational level, the Time factor has probably changed since World War II in that future conflicts are likely to be shorter. Consider that the V-1 and V-2 attacks lasted about 9 months and Operation Crossbow lasted almost 2 years. A modern conflict could certainly fall within these general timeframes. For example, Operation Desert Shield/Storm lasted 7 months. The difference, however, is that both World War II campaigns occurred in the context of a total war lasting for about 5 years. This difference becomes more relevant when examining the Time-Force relationship.

In World War II, the British had intelligence as early as 1939 that the German missile programs existed, but British efforts to gather more precise data were minimal. They delayed for two years before investigating Peenemunde, although they had

intelligence that it was involved in the program. It was not until 1943 that Britain reacted, and then perhaps too late. The point is that these events occurred in the context of a years-long, global, total war. Germany had time to develop and field the weapons, and the Allies had the time and the forces to attempt to delay the program.

The modern operational commander is unlikely to be placed in this situation for two reasons: 1) modern wars will likely be short, and 2) weapons development programs take years. Even Desert Shield/Storm was not long enough to enable Iraq to develop and field completely new weapons systems. Thus, today's operational commander will likely face an enemy with known capabilities and who is unlikely to develop new ones during the conflict.

Arguably, one exception to this case might be an enemy who purchases a new capability from a third party. If so, the new system would still have to be delivered and the enemy trained in its use. In a short conflict, this is unlikely to occur. A second exception might occur in a military operation other than war (MOOTW) of extended duration, such as the current Bosnia peace enforcement operations, in which a hostile party could develop or acquire a capability that could threaten other parties involved. In this case, the operational commander would face essentially the same problem the Allies faced in World War II. Given intelligence indicating the existence of a development or acquisition program, the operational commander will face the issue of taking steps to counter the program. The time available to do so may be short, other political and strategic considerations will almost certainly pertain, and the commander will have to decide which of his limited resources to apply.

From the Time-Force perspective then, it seems that in a shorter conflict, there will be less time to build to the resource levels seen in a total war, and little time to respond to new or developmental enemy capabilities. Both sides are likely to "come as they are."

c. FORCE

It is in the Force factor and its relationship to Space and Time that the most significant changes occur from the situation in World War II. Let us first consider the threat the Allies faced and how that threat has changed, and then examine the Allied response to the V weapons and how those capabilities have changed.

The Threat

Perhaps the most significant changes in the missile threat since World War II have been in missile accuracy and range. The V-1 Circular Error Probable (CEP)[10] at 130 miles range was about 8 miles. The V-2 CEP at 200 miles range was about 14 miles.[11] Obviously, the accuracy of these weapons contributed to their use only against area targets, while their range limited their overall target set. (However, as will be shown later, accuracy was not the only factor in target selection.) Modern ballistic and cruise missiles, on the other hand, generally have a higher accuracy and longer ranges. There are exceptions, such as the SCUD ballistic missile, but incorporating GPS technology into missile guidance systems is expected to continue to enhance accuracy.[12] Today's commander is now forced to defend both point and area targets against missile threats,

and must do so at longer ranges from the threat. The increases in missile accuracy and range have thus altered this Space-Time-Force relationship from that of World War II.

The operational commander must now consider how to defend an increased area, with potentially less time to do so, and with more impact on his forces. For example, the commander may be forced to put his forces in a defensive posture earlier in time and farther from the battlespace, thereby reducing their flexibility and speed of movement or maneuver. The enhanced threat will force the prioritization of potential targets and the allocation of what is likely a limited number of Active Defense assets. The threat may also force the allocation of Attack Operations assets, such as air power, which might be better used towards other objectives.

Another aspect of the Space-Force relationship related to missile accuracy is the link between potential missile targets and the attacker's intended role for the weapons. For example, because Hitler considered the V weapons to be terror weapons, their target set consisted principally of English cities.[13] To some extent, this target selection was a result of the inherent inaccuracy of the V weapons, but their inaccuracy was not the driving factor in Hitler's decision to use the weapons in terror attacks. Hitler's intent was to terrorize the British in revenge for the Allied strategic bombing campaign.[14] Evaluating enemy intent is important because it affects TMD planning and execution as much as does missile capabilities.[15]

A second significant change in missile capabilities has been their increased tactical mobility. While the V-1 missile was launched from fixed sites, V-2 launchers had a limited degree of mobility and required only a level area for set-up and launch. Modern ballistic

and cruise missiles are becoming increasingly mobile, and many are literally able to set-up, shoot, and depart within minutes.[16]

This mobility increase since World War II affects the Space-Force relationship inherent in Attack Operations. In World War II, the relatively mobile German forces operated effectively in a large area of France, Belgium, and the Netherlands. While the Allies located some V-1 launch sites fairly easily, they missed most of the small launch sites, and were unable to locate V-2 sites.[17] This Space-Force relationship has not changed today, as Coalition SCUD-hunting efforts in Iraq demonstrated, and will become increasingly important as missile mobility increases. Indeed, until Active Defense capabilities improve, Attack Operations will remain the most desirable and effective means of degrading enemy missile capabilities. Efforts to alter this Space-Force relationship through improved C4I are critical to effective Attack Operations in the future.

A third significant area of change in the Force factor is in ballistic and cruise missile warhead types. As already noted, the V-1 and V-2 carried conventional 2,000 lb. high explosive warheads. These warheads caused a relatively small amount of physical damage and casualties overall, especially when compared to German strategic bombing, but had a significant psychological impact on the British populace and leadership.[18] With conventional warheads, modern missiles have essentially this same affect, and the Force factor is unchanged from World War II. However, operational planners must now consider the potential enemy use of WMD warheads. This radical change in the Force factor directly affects the Space-Time-Force relationship and requires the operational commander to prioritize targets that are especially vulnerable to WMD attack and then take actions to defend them. This prioritization must be based on both the physical and

psychological effect of WMD use. While some argue, perhaps rightly, that a tendency to overreact to such terror attacks against civilian targets exists, operational commanders will still have to factor such considerations into their planning.

The Allied Response

In the historical case, many aspects of the Allied response are directly associated with the tactical level of war but are still relevant to the operational commander because they affect operational level planning. These aspects cover the spectrum of TMD concerns from Attack Operations to Passive Defense. A few of these tactical-level aspects will be examined below.

As already mentioned, the Allies did not possess the technology to detect the V-2 at launch or along its trajectory. Even if V-2 launch detection had been possible, their high velocity and relatively short flight time provided little time to react and prevented any Active Defense. The only defenses against the V-2 were those passive means always in place and requiring no warning such as dispersion and camouflage. Because V-2 targets were urban areas, however, this form of Passive Defense was less effective. This lack of a tactical-level defense was a contributing factor in the increased Allied bombing effort. Thus, a tactical-level Force factor influenced an operational-level Space-Time-Force relationship.

The modern commander faces similar constraints in dealing with ballistic missile attacks but is no longer completely helpless. Satellite systems can detect ballistic missile launches, and missiles can be tracked in flight. Effective C4I systems can estimate impact

areas and rapidly convey this information to the operational commander, theoretically in time to react with both Active and Passive Defenses. Thus, though the Time factor at the tactical level has not changed, technology has altered the Time-Force relationship to give the defender at least a chance during ballistic missile attacks. This change also has operational-level effects outside the military arena. The operational commander must now consider how to convey information regarding missile attacks to non-U.S. entities such as coalition partners or host nation civil authorities. Requirements to do so can place additional demands and constraints on the commander's actions in terms of Space, Time, and Force.

Let us return again briefly to the tactical level of war in the examination of the Allied response. In contrast with the V-2, the V-1 in flight was detectable by radar, and the missile had a lower velocity and cruise trajectory. These factors provided a window of engagement for Allied Active Defenses, primarily aircraft and AAA, and enabled a Passive Defense response, however limited. The result was that over half of the V-1 missiles detected were brought down, and casualties due to V-1 attacks were lower because target areas could prepare for the missile arrival. For the modern commander, the tactical-level Force-Time relationship has not essentially changed. Cruise missiles, while faster, stealthier, and smarter, can still be detected and engaged by air and ground-based defenses, and Passive Defense efforts have some degree of effectiveness. The implication, then, is that the modern operational commander, while challenged by the modern cruise missile threat, faces essentially the same Space-Time-Force relationship as existed in World War II.

It is evident that tactical-level actions or events can directly affect the operational commander and the operational-level Space-Time-Force relationship. Of course, operational level events will also have an effect. Operational level planning must clearly take into account the possible military responses to missile threats, Passive Defense planning issues, as well as the effects of coalition involvement. All of these issues are seen in the historical case and have relevance today.

In the area of Active Defense, Allied operational level planners had to develop effective responses to missile attacks while relying on limited resources. For example, at the start of the V-1 attacks, tactical aircraft such as the Spitfire and Mustang had to be reconfigured to enable them to counter the V-1, airspace control procedures and missile engagement techniques had to be developed, and defensive air patrols flown, all while aircraft were also in demand to support Allied ground operations in Europe. Air defense assets such as antiaircraft guns and aircraft spotters, which were reallocated due to the reduced threat after the end of the Blitz, had to be reconstituted to deal with the emerging V-1 threat. The same problem arose when these assets were reallocated after the initial V-1 attacks ceased due to the loss of their land-based launch sites. Soon thereafter Germany began to air-launch V-1s from bomber aircraft and from a different threat axis than before. Once again, the Allies had to shift Active Defense resources in reaction.[19] Today's operational commander will face similar problems in the Active Defense arena. The enemy will do the unexpected. Fewer resources will be available and there will be competing demands for their allocation.

Unfortunately, the Space-Time-Force relationship evident in the demand for Active Defense resources is also present in the area of Attack Operations. As already noted,

Attack Operations conducted in World War II consisted primarily of Allied bombing efforts during Operation Crossbow. One source notes that approximately 40% of Allied bomber resources were diverted from Operation Overlord to Operation Crossbow.[20] In addition, tactical aircraft conducted sorties in an effort to counter the V weapons. As in the Passive Defense case, World War II operational commanders had to consider the Space-Time-Force relationship in their resource allocation and planning and execution of Attack Operations. Fortunately, two advantages for today's operational commander are the recognition that the TMD problem exists, as well as ongoing service and joint efforts to develop adequate doctrine and capabilities.

Finally, the affect of coalition partners on operational plans can be significant, especially when those partners are providing host nation support. Many decisions in this arena will occur at the strategic level where the operational commander has limited influence and often simply has to respond to higher directives. In the historical case, this is evident in the Allied decision to shift air assets to support Operation Crossbow. Another example is General Eisenhower's decision to support General Montgomery's proposal for Operation Market Garden, even though Eisenhower believed the operation was risky and not the most effective option.[21] The SCUD-hunting campaign of Desert Shield/Storm is an oft-cited example of this same issue. In all of these cases, political concerns beyond the control of the operational commander drove the reallocation of assets.[22]

6. LESSONS AND CONCLUSIONS

There are undoubtedly a variety of lessons to be learned from what is an admittedly brief review of a complicated historical case. Some of these lessons have relevance to today's operational commander, and many are already well embedded in today's doctrine. However, there are some key points which may be useful to take from this case, in part as a reminder of why doctrine exists as it does.

First, the Space-Force relationship inherent in theater missiles which is the underlying motivation for their use will remain a constant. Simply put, theater missiles provide the means to attack or influence an enemy from a great distance and from a position of relative security. The operational commander cannot disregard the potential for their use or delay in planning a response to them.

Second, the Time-Force relationship found in World War II is unlikely to recur in the near future. Conflicts are likely to be short and will not allow time to build resources, develop new capabilities, or respond to new enemy capabilities. Both sides will "come as they are." Not surprisingly though, operational commanders will face competing demands on their limited resources regardless of the length of the war. Even in World War II, commanders often did not possess the resources they felt necessary to adequately accomplish their mission.

Third, the Force factor has changed since World War II. Theater missile capabilities have improved in range, accuracy, mobility, and warhead variety (conventional and WMD). In addition, missile technology has proliferated and many nations now have the capability to field such weapons. These changes expand the roles of these weapons to include both purely military and terror targets, and place an increased burden on the

operational commander's planning and execution. The commander must consider both the capability and the intent of the enemy.

Fourth, the Force factor has changed since World War II in that TMD capabilities have also improved. These improvements, while obviously desirable, have expanded the scope of responsibility of the operational commander. Indeed, such improvements lend increasing importance to the question of prioritizing what is to be defended and what is an acceptable level of risk (i.e. what can be left undefended?). Moreover, these changes, when coupled with improved threat capabilities, underscore the importance of a focused, unified TMD effort. Such unity of effort is critical to future effectiveness of TMD.

Fifth, and finally, the involvement of coalition partners and the use of host nation support will undoubtedly place additional demands on the operational commander from a TMD perspective. Such requirements will often result from higher-echelon decisions over which the commander has little influence, and might include providing Active Defense assets and early warning, conducting training, or coordinating Attack Operations.

In conclusion, the insights gained from this historical case are not new or revolutionary. Instead, they reflect those issues which can be expected to consistently arise in TMD planning, and may serve as starting points for the operational commander and his staff. The commander will always face competing demands and requirements and, as in every other military endeavor, must prioritize and decide in response. The continued development of effective TMD doctrine, coupled with the acquisition of improved capabilities in all four "pillars" of TMD, and enabled through realistic training, should permit an effective TMD response in future conflicts.

NOTES

[1] Joint Chiefs of Staff, Doctrine for Joint Theater Missile Defense (Joint Pub 3-01.5) (Washington, DC: 22 February 1996.), viii.

[2] As discussed in Milan Vego, On Operational Art - Third Draft (U.S. Naval War College, September 1998).

[3] Ibid., 33.

[4] Ibid., 57.

[5] C.G.C. Treadway, More Than Just A Nuisance - When Aerial Terror Bombing Works (U.S. Air University. School of Advanced Airpower Studies, February 1998), 14.

[6] Ibid., 15.

[7] William C. Story, Third World Traps And Pitfalls - Ballistic Missiles, Cruise Missiles, And Land-Based Airpower (U.S. Air University. School of Advanced Airpower Studies, October 1995), 13.

[8] Frank W. Heilenday, V-1 Cruise Missile Attacks Against England: Lessons Learned and Lingering Myths From World War II (Santa Monica, CA: RAND Corp., 1995), 16.

[9] These numbers are approximately 15% of the total Allied sorties and tonnage dropped during that time period. Story, 13.

[10] The radius of a circle containing 50% of impacts.

[11] Heilenday, 7-9.

[12] Story, 37.

[13] With two exceptions, the targets were large areas instead of specific points. First, Antwerp became a target after the Allies captured it. This principal exception to the "terror weapon" role was a response to Allied use of Antwerp's port facilities. A second exception was an unsuccessful German attempt to destroy the Allied-held bridge over the Rhine at Remagen by launching V-2s in an effort to delay the Allied ground advance.

[14] David Johnson, V for Vengeance. (London: William Kimber & Co., 1981), 179.

[15] It is interesting to ponder the affect that V-1 attacks on the Normandy beaches might have had on the Allied landings. While the success of any such attacks would have been largely a matter of luck, even a few might have hampered the landings enough to provide the Germans with more time to react. A fear of such attacks was certainly present in Allied planning considerations. See Story, 14.

[16] Story, 21.

[17] The Allies were hampered by a belief that the V-2 also used fixed launch sites. As an alternative, the Allies devoted tactical aircraft to German supply train interdiction. They had some success but still could not prevent V-2 launches. See Story, 11-12.

[18] The resulting physical damage, though not irrelevant, was not on the same scale as that from the German bomber raids on London, especially in 1940-1941. For example, the number of British deaths due to German bombing was over 51,000, while the number killed by V weapon attacks was just under 9,000. See Treadway, 15.

[19] Peter G. Cooksley, Flying Bomb (New York: Charles Scribner's Sons, 1979), 100-122.

[20] Joint Pub 3-01.5, I-3.

[21] Operation Market Garden was intended primarily to capture a Rhine River crossing in support of the Allied advance. An additional bonus was to be the capture of V-2 launch areas in the Netherlands. However, the operation failed to capture the bridge crossing, resulted in significant Allied casualties, and only temporarily forced the V-2 units to withdraw from their normal operating areas. See Johnson, 135-146.

[22] Treadway, 32.

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