Army Fires Capabilities for 2025 and Beyond

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Preface

This report documents research and analysis conducted as part of a project entitled *Army Fires for Army 2025*, sponsored by the Field Artillery School at Fort Sill, Oklahoma (a part of the U.S. Army Training and Doctrine Command). The purpose of this project was to provide an independent assessment of the fires capabilities the Army will need, from the brigade combat team-level to echelons above division, in future conventional combined arms maneuver operations in the 2025 and beyond timeframe, and determine options for meeting these fires requirements from both organic Army as well as joint systems. The assessment includes direct support, long-range strike, counterfire, the associated target acquisition requirements, and mission command issues. The majority of the research for this project was conducted in 2016–2017. The document then went through a lengthy security review that was completed in August 2019, when it was determined that the report could be released to the public.

This research was conducted within the RAND Arroyo Center's Forces and Logistics Program. RAND Arroyo Center, part of the RAND Corporation, is a federally funded research and development center sponsored by the United States Army.

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U.S. Army. The views of sources utilized in this study are solely their own and do not represent the official policy or position of DoD or the U.S. Government.

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Summary

The research reported here, conducted for the Commandant of the Field Artillery School at Fort Sill, Oklahoma, is representative of the recent Army reorientation toward conventional combat operations. Focusing on the period 2016–2030, the research had these objectives:

- **Task 1:** Determine the possible operational environment of the 2025 and beyond time frame.
- **Task 2:** Establish the already planned and programmed fires capabilities of the Army and other services.
- **Task 3:** Determine the likely conventional threats that U.S. fires units can expect to confront, both in terms of hostile intelligence, surveillance, and reconnaissance (ISR) and counterfire threats to U.S. artillery and joint fires systems and in terms of targets that the Army and joint fires will be expected to engage.
- **Task 4:** Determine required fires capabilities.
- **Task 5:** Develop overall recommendations.

U.S. Army field artillery has been recognized as one of the most powerful and important branches of the service since at least World War II. Even during the "hybrid" warfare period of Vietnam (1964–1972), which included a mix of conventional combat and counterinsurgency (COIN), the field artillery played a major role. Operation Desert Storm of 1991 also included a very large amount of field artillery to support the armored units that led the advance to liberate Kuwait.

Operation Iraqi Freedom utilized a much smaller ground force compared with Desert Storm of 12 years earlier, both in terms of maneuver units and field artillery. Importantly, by late 2003 U.S. forces in Iraq had to confront a growing insurgency; meanwhile, the Taliban was already regaining much of its former strength in Afghanistan. By 2004, the focus of the U.S. Army elements in both countries was on COIN, and the service increasingly emphasized COIN as time went on. This multiyear focus on COIN had considerable effects on U.S. Army training, equipment priorities, and overall institutional orientation, including the field artillery branch.

By 2013, there was renewed interest in preparation for conventional combat. Aggressive moves by Russia against Crimea and Ukraine, fear of Russian coercion against the Baltic nations, an expanding Iranian military, and rapidly growing Chinese military capabilities all contributed to the revived U.S. interest in conventional operations. However, when the Army started to examine the state of its combat arms branches, it discovered that the decade of COIN had resulted in an atrophy of training for high-intensity combined arms operations, equipment deficiencies, and a lack of expertise for these types of operations on the part of most middle grade and junior leaders.

Advances in the Fires Capability of Other Nations

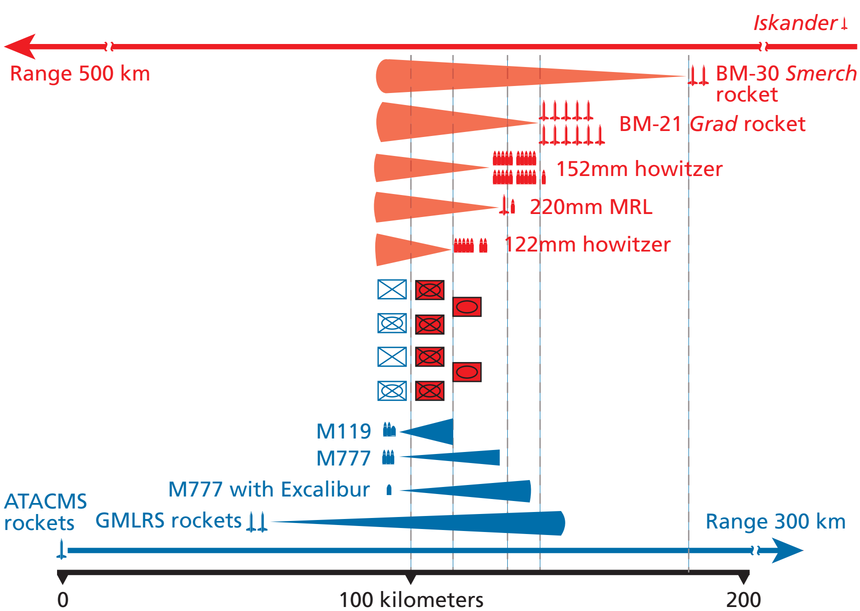
While the U.S. Army's field artillery branch was dealing with the implications of COIN from 2003 to the present, the militaries of a number of potential competitor nations made significant advances. For example, as of 2017, the Russian Army has made considerable advances in its artillery. Key Russian artillery capabilities include long-range multiple rocket launchers, such as the BM-30 *Smerch*, which can fire a wide variety of warheads up to 90 km. The SS-26 *Iskander* short-range ballistic missile also fires various warheads (including nuclear weapons) against targets at ranges of over 400 km. The Russian Army has deployed large numbers of cannons and rocket launchers at the brigade and battalion tactical group levels. When combined with a growing, multifaceted targeting and reconnaissance capability, Russian artillery is a formidable potential opponent.

Other nations, such as Iran and the People's Republic of China, are also improving and expanding their fires capabilities. Like the Russians, both the Iranians and Chinese have fielded new types of multiple rocket launchers. Some Chinese multiple rocket launchers (MRLs) have ranges in excess of 200 km, and those ranges are projected to increase in coming years.

Target acquisition systems are also improving in countries that could be military opponents at some point in the future. Just as the U.S. military has greatly expanded its use of unmanned aerial systems (UASs) since the start of Operation Enduring Freedom in 2001, other militaries have followed a similar course of action, adding new UAS capabilities.

Figure S.1 shows a simple comparison of U.S. Army field artillery and its counterpart systems in the Russian Army. The text in the main body of this report elaborates on areas where U.S. Army artillery

Figure S.1
U.S. Army Fires Compared with Russian Fires in a Baltics Scenario



NOTES: MRL = multiple rocket launcher; ATACMS = Army Tactical Missile System; GMLRS = Guided Multiple Rocket Launch System.

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would face challenges should it have to fight the Russian military or a similarly well-armed opponent.

In addition to examining the state of U.S. Army field artillery, this research included a review of the fires-related plans of the other services. All future operations will be joint, and the Army can benefit from the capabilities of the Air Force, Navy, and Marine Corps. Similarly, the other services will benefit from the Army's fires and ISR systems.

Key Recommendations

- Increase the number of field artillery units that can deploy quickly to a crisis or that are located forward, where the fast arrival of U.S. forces is essential; this is likely to require force structure increase for the active Army field artillery units and/or changing the readiness status of some National Guard field artillery units.
- Improve the Army's ability to quickly get and utilize ISR data from the other services.
- Modernize the Army's cannon systems, particularly in terms of range and rate of fire.
- Ensure that there is a timely and adequate replacement for the Army Tactical Cruise Missile System (ATACMS).
- Improve Army ground forces target acquisition capabilities.
- Improve the artillery's ability to provide fire support to allied and coalition partners.
- Enhance the field artillery's electronic warfare (EW) and cyber resilience.
- Reduce the artillery's vulnerability to enemy fires through reduced exposure to EW targeting, improved mobility, and use of camouflage and decoys.
- Improve the survivability of artillery units against enemy indirect fire, airborne, and ground threats.
- Emphasize major conventional opponents in field artillery, combined arms, and joint training exercises.

- Examine the possible use of foreign fires systems that may be have utility to the field artillery.
- Continually assess technology trends that could improve the effectiveness of field artillery units.

Acknowledgments

The RAND research team wishes to express its appreciation to a number of individuals and organizations that helped facilitate the research. Colonel Heyward Hutson and Craig Newman were the primary points of contact at the Fires Center of Excellence (FCOE) at Fort Sill. They helped determine the parameters of the research and were instrumental in obtaining access for the RAND research team with agencies within FCOE and elsewhere. Also at Fort Sill, Colonel Thomas Williams and Colonel Robert Magee and their staffs provided excellent support for the research. Captain Eric Barton at FCOE set up numerous meetings for the research team, including meetings with Marine Corps and allied field artillery representatives at Fort Sill.

Within Army Research and Development Command (RDECOM), Donald Carlucci, senior research scientist at Picatinny Labs, introduced the research team and set up several Army Armament Research, Development and Engineering Center meetings at both Watervliet Arsenal and Picatinny, where information on artillery cannons and their ammunition was provided. Also within RDECOM, Michael Turner and his team at the Fire Support Capability Area at Huntsville, Alabama, provided very valuable information on the Army's plans to improve its field artillery rockets and missiles.

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CHAPTER ONE

Introduction

The attacks on New York and Washington, D.C., in September 2001 caught the U.S. military, like the rest of the nation, by surprise. Although the Soviet Union had collapsed roughly a decade earlier, the U.S. military was still largely focused on preparing for conventional combat operations against the armed forces of other nation-states. Regional opponents had replaced the Soviets and Warsaw Pact in U.S. planning, and there was increasing concern about the rising military power of the People's Republic of China; relatively little attention was given to irregular warfare.

Neither the early 2002 overthrow of the Taliban nor the major combat phase of Operation Iraqi Freedom (OIF) in the spring of 2003 included an insurgency. By the end of 2003, that situation had changed, as coalition forces were confronted with rapidly growing resistance in both countries. As time passed, the focus of the Army moved increasingly toward counterinsurgency (COIN). This multiyear focus on COIN had considerable effects on the U.S. Army's training, equipment priorities, and overall institutional orientation.

By 2013, there was renewed interest in preparation for conventional combat. Aggressive moves by Russia against Crimea and Ukraine, fear of Russian coercion against the Baltic nations, an expanding Iranian military, and rapidly growing Chinese military capabilities all contributed to the revived U.S. interest in conventional operations. However, when the Army started to examine the state of its combat arms branches, it discovered that the decade of COIN had resulted in an atrophy of training for high-intensity combined arms operations, equipment deficiencies, and a lack of expertise for these types of operations on the part of most middle and junior leaders.

This research, conducted for the Commandant of the Field Artillery School at Fort Sill, Oklahoma, is representative of the recent Army reorientation on conventional combat operations. A number of key assumptions guided the research: (1) the mission of the field artillery would remain essentially the same in the time frame of the research; (2) the focus of the work would be on capabilities required to fight major opponents, as opposed to COIN-type operations; (3) material solutions that are currently under development by the Army would be prioritized rather than completely new systems that would require a decade or more of research and development in order to be viable options for the field artillery and would therefore be beyond the time frame of this study; and (4) the research would use as a basis for analysis the current modernization programs of the other services rather than hypothesizing that one or more of the other services would develop an entirely new fires or intelligence, surveillance, and reconnaissance (ISR) capability during the time frame of the study.

Focusing on the period from 2016 to roughly 2030, the research had these objectives:

- **Task 1**: Determine the possible operational environment of the 2025–2030 time frame.
- **Task 2:** Establish the already planned and programmed fires capabilities of the Army and other services.
- **Task 3:** Determine the likely conventional threats that U.S. fires units can expect to confront, both in terms of hostile ISR and counterfire threats to U.S. artillery and joint fires systems and in terms of targets that the Army and joint fires will be expected to engage.
- **Task 4:** Determine required fires capabilities.
- **Task 5:** Develop overall recommendations.

Contrasting the Counterinsurgency Environment to Today's Conventional Combat Realities

U.S. Army field artillery has been recognized as one of the most powerful and important branches of the service since at least World War II. Even during the "hybrid" warfare period of Vietnam (1964–1972), which included a mix of conventional combat and COIN, the field artillery played a major role. Operation Desert Storm of 1991 also included a very large amount of field artillery to support the armored units that led the advance to liberate Kuwait.

OIF utilized a much smaller ground force compared with Desert Storm of 12 years earlier, both in terms of maneuver units and field artillery. Importantly, by late 2003 U.S. forces in Iraq had to confront a growing insurgency; meanwhile, the Taliban was already regaining much of its former strength in Afghanistan. By 2004, the focus of the U.S. Army elements in both countries was on COIN. This had a major effect on the field artillery branch.

As the years passed from 2004 to the December 2011 withdrawal of U.S. forces from Iraq, the role and quantity of field artillery underwent considerable change. U.S. forces in both Iraq and Afghanistan utilized semifortified forward operating bases (FOBs). Field artillery tended to be dispersed among those locations.

Due to the abundance of fixed-wing air support and large numbers of Army attack helicopters, Army units conducting patrols, area security, or quick-response missions from their FOBs tended to rely on those assets as the main sources of fire support when contact was made with the enemy. Because of the great distances between operating bases, field artillery was often out of range of a troops-in-contact location, and when artillery was available it was usually a small number of weapons that could range the target, often a handful of howitzers at one time. The "massing of fires" that in past years was such an important concept to field artillery units was often impossible, impractical, or inappropriate in the protracted COIN phase of OIF and Operation Enduring Freedom (OEF).

Field artillery units often were employed in a military police–like role in both countries, with their troops used to guard convoys, checkpoints, and other locations. While important missions, the use of field artillery units in this manner contributed to a steady atrophy of the field artillery skills of officers and enlisted personnel (U.S. Government Accountability Office [GAO], 2007b, p. 83). Simultaneously, field artillery force structure was reduced by roughly 50 percent in the 2004 to 2011 period. The appendix, "Army Indirect Fires in an Operational Context: A Historical Analysis (1985–2003) with a View Toward the Baltics (2020)," discusses in more detail the evolution of Army artillery, in weapons and force structure, from the Cold War through Operation Desert Storm and OIF to today, along with what that evolution may imply for Army artillery in a future conflict with Russia in the Baltic states.

All the realities mentioned above resulted in the Army's field artillery of 2017 having far less experience and capability compared with their predecessors of the pre-9/11 era. And during the years that U.S. field artillery was employed for many non-artillery missions, ominous trends were underway in rising competitor nations.

Advances in the Fires Capability of Other Nations

While the U.S. Army's field artillery branch was dealing with the implications of COIN from 2003 to the present, the militaries of a number of potential competitor nations made significant advances. Whereas at the time of the 9/11 attacks the Russian military was very weak, in 2017 the Russian Army has made considerable advances in its artillery capability. Key Russian artillery capabilities include long-range multiple rocket launchers, such as the BM-30 *Smerch*, which can fire a wide variety of warheads up to 90 km. The SS-26 *Iskander* short-range ballistic missile also fires various warheads (including nuclear weapons) against targets at ranges of over 400 km. The Russian Army has deployed large numbers of cannons and rocket launchers at the brigade and battalion tactical group levels. When combined with a growing, multifaceted targeting and reconnaissance capability, Russian artillery is a formidable potential opponent.

Other nations, such as Iran and the People's Republic of China, are also improving and expanding their fires capabilities. Like the Russians, both the Iranians and Chinese have fielded new types of multiple rocket launchers (MRLs). Some of the Chinese MRLs have ranges in excess of 200 km, and those ranges are projected to increase in coming years.

Target acquisition systems are also improving in countries that could be military opponents at some point in the future. Just as the U.S. military has greatly expanded its use of unmanned aerial systems (UASs) since the start of OEF in 2001, other militaries have followed a similar course of action, adding new UAS capabilities.

When one compares the reduction in U.S. Army field artillery capabilities and capacity from 2003 to the present, the growth of the fires capability of other nations should be a cause of considerable concern.

Purpose of This Research

Based on the list of research tasks shown earlier, in this report we examine the types of operations that U.S. Army field artillery could be expected to conduct in the future, seek to identify what today's capability gaps are, and propose courses of action. Importantly, this Army-focused research also seeks to understand and account for the fires capabilities of the other services.

The use of fires is very much a joint force issue. In some cases (strike operations), joint fires will be applied when no Army ground forces are part of the operation. In other cases, fires will be used far from Army forces (interdiction), although the Army is part of the overall operation. Additionally, joint fires can be applied in close support of Army ground units. One of the chapters of this report focuses on the fires capabilities of the U.S. Air Force, U.S. Navy, and U.S. Marine Corps. Army fires complement those of the other services, and the Army is often dependent on the support provided by the Air Force, Navy, and Marine Corps. In turn, the other services may rely on Army fires. Army fires to suppress or destroy enemy air defenses are an important example of how the Army can help enable air operations by the other services.

Ultimately, this research is intended to help the Army identify areas where it should improve its field artillery capability and capacity, with a focus on conventional combat operations. Today and for the foreseeable future, the Army will be making choices in an era of constrained budgets. All the choices it makes will be difficult ones. The field artillery branch is currently at a low point in terms of its capacity and capabilities when compared with potential high-quality opponents.

The majority of the research for this project was conducted in 2016–2017. The document then went through a lengthy security review that was completed in August 2019, when it was determined that the report could be released to the public.

The report is organized as follows:

Chapter 1: Introduction
Chapter 2: Illustrative scenarios
Chapter 3: Threats
Chapter 4: Current and potential Army field artillery capabilities
Chapter 5: Joint fires capabilities
Chapter 6: Targeting
Chapter 7: Capability gaps
Chapter 8: Recommendations.

The next chapter describes select scenarios that show the types of operations that the Army could be expected to conduct in the future. Due to the focus of this research, most of the scenarios are conventional combat against the armed forces of another nation-state. The likely implications for the field artillery are discussed in each scenario.

CHAPTER TWO

Future Army Fires Planning Scenarios

Introduction

The United States faces a rapidly changing security environment. After 15 years of waging counterinsurgencies in Afghanistan and Iraq, the U.S. Department of Defense (DoD) is repositioning to focus on emerging strategic challenges and opportunities. We are seeing new technologies, new centers of power, and a more volatile and unpredictable world that is in some instances more threatening to the United States. Ballistic missile, precision strike, unmanned system, space and cyber, and weapon of mass destruction (WMD) technologies are rapidly diffusing around the world. Modern warfare is evolving rapidly, and battlespace in the air, sea, space, and cyber domains, in which our forces have enjoyed dominance, is becoming increasingly contested. Our allies and partners face dynamic and unpredictable security challenges, particularly from Russia, North Korea, and Iran. Violent extremism and sectarian conflict persist from Africa to South Asia. In the worst manifestation, the Islamic State of Iraq and the Levant (ISIL) is brutally occupying parts of Iraq and Syria and is threatening to expand across the region. Finally, China remains a near-peer competitor with growing military capabilities whose aggression the United States must deter (DoD, 2014a; White House, 2015; Joint Chiefs of Staff, 2015).

U.S. defense strategy calls for, *inter alia*, deterring potential adversaries, defeating interstate aggression, and disrupting and defeating violent extremist organizations (VEOs). Considering the scenarios in which the U.S. Army could be called upon to fight helps ensure the development of the military capabilities necessary to implement U.S.

strategy. In addition to considering the most likely scenarios, it is worthwhile to consider potentially less likely scenarios that require capabilities not required in others. After evaluating the emerging security environment and taking into account the types of operations required in different scenarios, we selected potential conflicts with the following adversaries as the basis for assessing future Army fires requirements: Russia, North Korea, Iran, ISIL, and China.

This chapter presents future scenarios involving each of those potential adversaries, with the goal of illustrating the nature of the opposition that U.S. forces would likely face in engaging them, as well as other unique circumstances, such as mission, geography, and terrain, that could drive U.S. capability requirements. Because this study is concerned with the time frame of 2020–2035, postulated scenarios necessarily represent only single points within ranges of possible futures. International relations and defense policies can change, and nonstate entities such as ISIL can transform or even disintegrate between now and ten or more years hence. Nevertheless, the scenarios provide real-world, joint force contexts for holistically evaluating friendly and potential enemy capabilities. The consideration of several different scenarios helps to ensure that capabilities are evaluated under the potentially different circumstances in which the Army might find itself in future conflicts.

Over the course of presenting the future scenarios, this chapter also contrasts the likely nature of the operations in the scenarios with operation of Army artillery in the past. The goal is to highlight the developments of fires-related capabilities needed to ensure the ability to implement U.S. defense strategy into the future. It should be noted that we did not try to assess the likelihood of any of the scenarios that are included in this chapter. All are plausible and could occur at some point in the future. Fortunately, some of the most dangerous scenarios (possible clashes with Russia or China) are not likely to occur, but the U.S. military still must be prepared for these kinds of situations. On the other hand, the current tensions on the Korean Peninsula probably mean that that scenario is significantly more likely to occur than the Russian or China cases.

The mission, threat, and terrain vary considerably in these scenarios. Most of these illustrative operations would be conducted against conventional opponents (ISIL is the main exception, but U.S. forces operating in Iran would also face a hybrid threat of both conventional and irregular Iranian forces). Depending on the scenario, the terrain would vary considerably, from the mountains of Korea to open desert conditions in Iran or Iraq/Syria. In all the scenarios, the amount of urbanization is increasing over time. Given the U.S. reluctance to cause significant numbers of civilian casualties, even in a major combat situation, the reality of increased urbanization means that fires would have to be employed carefully, and commanders may require a wider suite of precision indirect fire munitions than is the case today.

The Army, including the field artillery, will never have enough resources to be prepared for all possible future contingencies. This reality means that priorities will have to be set and resources allocated in an appropriate manner, including a determination of whether is it more prudent to prepare for the most likely potential crises or to emphasize the most threatening ones.

Russia

Europe is the region with which the United States has the strongest ties and it is home to our most stalwart and capable allies and partners. While most European countries are working to maintain international security, continued instability in the Balkans and on the European periphery will continue to pose a security challenge. In particular, Russia has been modernizing its military in many respects, has recently violated Ukraine's sovereignty and territorial integrity, and has taken a belligerent stance toward other neighboring countries. Potential Russian aggressions against its neighbors will present risks into the foreseeable future.

One demanding but plausible conflict scenario involving Russia is an attack on the Baltic states: Estonia, Latvia, and Lithuania. All three are contiguous to Russian territory and spent many years as component republics of the Soviet Union. Like Ukraine, Estonia and Latvia are home to sizable ethnic Russian populations that have not been well integrated into the two countries politically and socially, which could give Russia an excuse to meddle in Estonian and Latvian affairs. It is presumed in this scenario that once the conflict occurs, Russian goals would be to isolate the Baltic states to coerce their withdrawal from NATO, thereby reconstituting Russia's security zone and inflicting a strategic defeat on NATO.

The United States and the other members of NATO are obligated, under Article V of the North Atlantic Treaty, to come to the Baltic states' defense if they are attacked. Recent analysis has shown that it would be very difficult for NATO to defend the Baltic states without forces stationed there beyond the Baltics' own militaries (Shlapak and Johnson, 2016). Thus, this report postulates that by 2025, NATO will have forces in the Baltic states, along with prepositioned equipment that would be used in their defense.

Theater Geography

How a conflict with Russia in the Baltics might unfold would be driven a great deal, as most scenarios are, by the geography. The location of the Baltic states, adjacent to Russia and Belarus, and their narrow overland connection to the rest of NATO (Poland) make the defense difficult (Figure 2.1). Russia also possesses an enclave, in Kaliningrad, that is well positioned for interference with the movement of NATO forces into the Baltics. The borders that Estonia, Latvia, and Lithuania share with Russia and Belarus are roughly the same length as the one that separated West Germany from the Warsaw Pact—1,467 km (911 miles). Important distances in the theater are relatively short for the postulated Russian attackers and longer for NATO defenders. From the Russian border to Tallinn (Estonia) along the main highways is about 200 km. The highway distance from the Russian and Belarusian borders to Riga (Latvia) is between about 210 and 275 km. From Belarus to Vilnius (Lithuania) is only about 30 km. To move from Poland into the Baltics (Lithuania) by land, NATO forces would have to transit the "Kaliningrad corridor," a 110- to 150-km-wide gap between the Russian enclave and Belarus that could be attacked from both sides and would require forces to secure. The distance from the

Figure 2.1
The Baltic States

SOURCE: Shlapak and Johnson, 2016b.
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Polish border to Riga is about 325 km; to Tallinn, almost 600 km (from the border to Vilnius is about 120 km). Instead of moving overland from Poland, NATO forces could arrive by air or by sea, but they would have to contend with Russian interdiction from Russia proper, Kaliningrad, and Belarus.

The terrain in the Baltics region is mixed, with large open areas interspersed with forests, lakes, and, in some places, sizable wetlands. Off-road mobility in places could be difficult, especially for wheeled vehicles. There is, however, a fairly robust network of roads and highways throughout, and there are few large rivers to serve as natural defensive lines and barriers to movement. There are significant built-up areas in and around cities, but otherwise the region is mostly rural.

The Conflict

It is assumed that the conflict would occur after a political crisis that provided a few weeks of warning. Russian ground forces would be massed in the Western Military District, Belarus,[1] and Kaliningrad, for a multipronged attack on the Baltics. They would consist of 50 to 60 battalion tactical groups (BTGs),[2] plus 15 fires battalions and six attack helicopter battalions. Supporting Russian air forces would consist of 25 squadrons of fixed-wing tactical aircraft, based in Russia and Belarus, and two squadrons in Kaliningrad. Russia would also have deployed extensive anti-access/area denial (A2AD) and sensor-strike systems—tactical ballistic missiles, long-range rockets, anti-ship missiles (ASMs), long-range surface-to-air missiles (SAMs), and submarines—to prevent the movement of NATO forces into theater and hinder NATO air operations. They could also attack NATO ground forces and logistics targets. Finally, the Russian offensive would be supported by special operations forces (SOF); ISR; sophisticated cyber and electronic warfare (EW); and, potentially, anti-space capabilities. The postulated Russian order of battle is shown in Tables 2.1 and 2.2.

The Russian operational plan would be to attack and occupy Estonia and Latvia and delay and defend in Lithuania to deny NATO

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[1] Russian and Belarusian militaries cooperate closely; Russia and Belarus conduct frequent large joint exercises (Zdanavicius and Czekaj, 2015).

[2] Russian ground forces are typically organized in brigades, but Russian practice is to generate one ready battalion tactical group from each brigade. Hence, this report denominates Russian Army forces as battalions.

Table 2.1
Russian Ground Forces

Type	Quantity
Maneuver battalions	
Tank	12
Mechanized infantry	12
Motorized infantry	15
Airborne	18
Naval infantry	3
Total	60
Artillery battalions	
Tube artillery	12
Heavy rocket launcher	9
Medium rocket launcher	24
Total	45
Surface-to-surface missile battalions	
Iskander short-range ballistic missile	2
Tochka very short-range ballistic missile	3
Total	5
Attack helicopter battalions	6

SOURCE: International Institute for Strategic Studies, 2016.

the ability to successfully counterattack. The main attack would comprise nine brigades driving westward from Russia toward Riga, supported by two brigades driving northwestward from Belarus. Four brigades would drive westward from Russia toward Tallinn. Three brigades would drive northwestward from western Belarus to try to cut the Kaliningrad corridor. Two brigades would defend in Kaliningrad.

NATO forces initially available for the defense are assumed to include those from the Baltic states plus NATO forces that would flow

Table 2.2
Russian Air Forces

Type	Squadrons
Su-27 Flanker	9
Su-34 Fullback	2
MiG-29 Fulcrum	3
MiG-31 Foxhound	4
Su-24 Fencer	5
Tu-22M3 Backfire	4
Total	27

SOURCE: International Institute for Strategic Studies, 2016.

into the theater during the period of warning. The Baltic states provide 11 lightly armed infantry battalions, which are deployed to delay the Russian advance along major avenues of approach to their capital cities. One U.S. infantry brigade combat team (IBCT) (the 173rd Airborne Brigade Combat Team), one U.S. armored brigade combat team (ABCT) (of the three utilizing equipment assumed to be prepositioned in the Baltics or Poland), and one U.S. Marine Expeditionary Unit would defend Tallinn. Two U.S. IBCTs (from the 82nd Airborne Division) and one U.S. ABCT would defend Riga. One U.S. ABCT and one U.S. Stryker brigade combat team (SBCT) (utilizing equipment assumed to be prepositioned in Germany and other NATO countries) would defend Vilnius. One U.S. combat aviation brigade (CAB), three field artillery brigades (FABs) (also constituted from prepositioned equipment), plus Patriot SAMs and supplemental short-range air defense systems (SHORADS) would also be deployed in the Baltics. Three NATO ABCTs would move into Poland and prepare to move into Lithuania.[3] U.S./NATO high-level headquarters and stra-

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3 Polish forces are assumed to be defending Poland—especially the 200-km border with Kaliningrad—and securing NATO's rear area. Thus, they are not available to participate in the direct defense of the Baltic states.

tegic assets could be located in Europe outside the Baltic states. Supporting NATO air forces would consist of 37.5 squadrons of fixed-wing tactical aircraft based in central Europe, in Sweden,[4] and on one U.S. aircraft carrier. The NATO defense would also be supported by SOF, ISR, cyber, and EW capabilities. The postulated NATO order of battle is shown in Tables 2.3 and 2.4.

The Russian operational plan and the NATO defense are illustrated in Figure 2.2.

A conflict with Russia in the Baltics would likely be very intense, much more like what was expected in Germany during the Cold War than what U.S. forces have experienced since then. At the outset of the battle, Russian A2AD/sensor-strike systems would launch a massive attack on NATO targets in and around the Baltic states (Figure 2.3). To prevent NATO movement by sea, Russia would employ ASMs with a 300-km range from Kaliningrad, ASMs from aircraft, and submarines in the Baltic Sea against NATO transport ships. It would strike ports, airfields, and prepositioned equipment sites with missiles. To hinder NATO air operations, it would strike selected airfields with missiles, conduct mass fighter sweeps, and employ long-range integrated air defense systems (IADSs) that can range over the Baltic states and parts of Poland. It would hit command, control, and communication (C3) targets, rail networks, and bridges in Poland. Russian missiles, rockets, and close air support (CAS) aircraft would attack U.S./NATO armored forces. Russian cyber and EW capabilities would attempt to degrade NATO C3, ISR, and fires capabilities.

Compared with the capabilities of the Soviet Union during the Cold War, today's Russian forces are much smaller, but they have the ability to locate U.S. and NATO assets throughout the European theater and engage targets with precision weapons as far away as France and the United Kingdom. Therefore, the United States and its allies

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[4] The assumption of Swedish participation on the side of NATO is based on informal discussions with Swedish defense officials. The use of Swedish airbases allows NATO to avoid IADS in Kaliningrad, although with the large number of potential bases available in central Europe, it likely would not have a large impact on the outcome of the operation.

Table 2.3
NATO Ground Forces, Russia Scenario

Country	Type	Quantity
	Maneuver battalions	
Estonia	Infantry	2
	Light Infantry	3
Latvia	Light Infantry	2
Lithuania	Mechanized infantry	2
	Motorized infantry	2
United States	Combined arms	10
	Mechanized infantry	3
	Motorized infantry	16
NATO	Combined arms	3
	Mechanized infantry	8
	Total	51
	Artillery battalions	
United States	Tube artillery	6
	Rocket launcher/missile	3
NATO	Tube artillery	1
	Total	10
United States	Attack helicopter battalions	2

SOURCE: International Institute for Strategic Studies, 2016.

will have to employ appropriate passive and active measures to reduce or negate the types of threat they could face.

On the ground, Russian forces would drive into Estonia and Latvia, ultimately encountering NATO forces in the vicinity of Tallinn and Riga. In Lithuania, they would try to close the Kaliningrad gap to block the arrival of NATO reinforcements from Poland. Russian forces would likely isolate Tallinn and Riga, but they would lack the combat

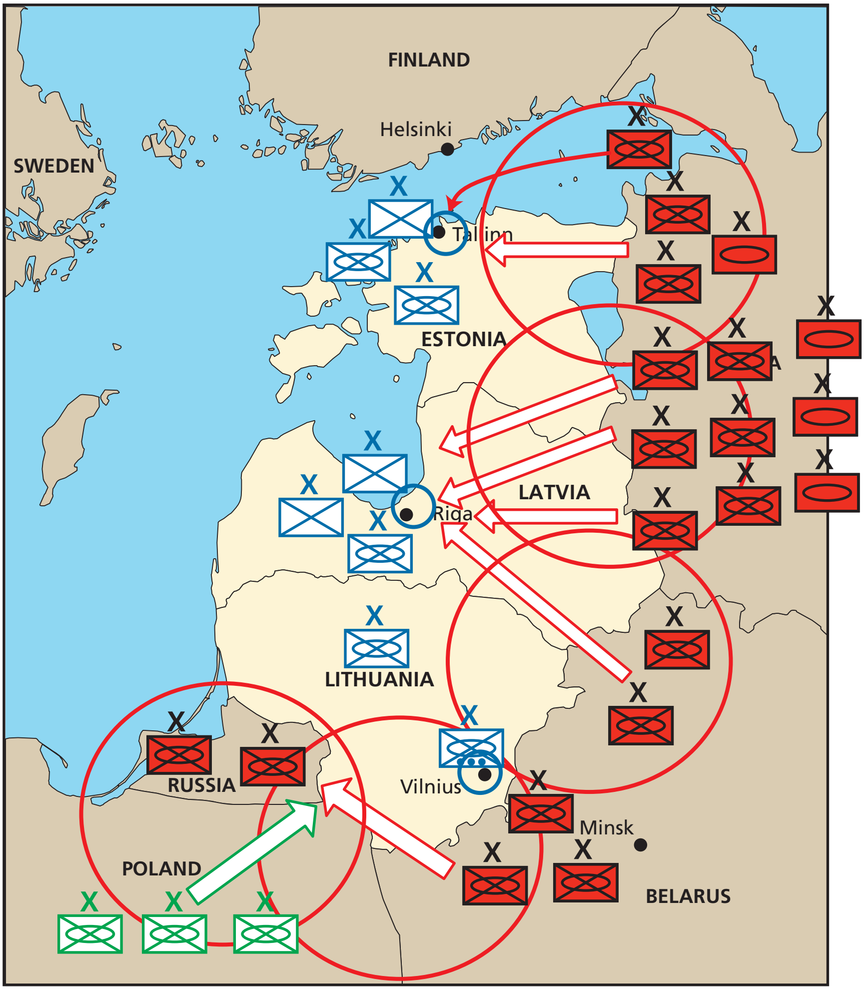
Table 2.4
NATO Air Forces, Russia Scenario

Country	Type	Squadrons
United States	F-15C	4
	F-15E	4
	F-16	4
	F-22	6
	F-35	10
	F/A-18	2
	B-1	1
	B-2	1
United Kingdom	Tornado	1
	Typhoon	1
France	Rafale	1
Norway	F-16	1
Canada	CF-18	0.5
Denmark	F-16	1
	Total	37.5

SOURCE: International Institute for Strategic Studies, 2016.

power to assault the cities quickly and successfully. At that point, they would assume the defensive, continue to block further NATO access, and begin artillery attacks on NATO forces there. In Lithuania, the U.S. forces deployed around Vilnius and the NATO forces arriving from Poland could link up, but they would lack the additional combat power needed to relieve Riga (and Tallinn). In just that short time, both sides could suffer significant ground force losses—potentially up to one-third each, from direct ground combat and enemy fires. The question then would be how long NATO forces in Riga and Tallinn could hold out—possibly a few weeks—while NATO continued to

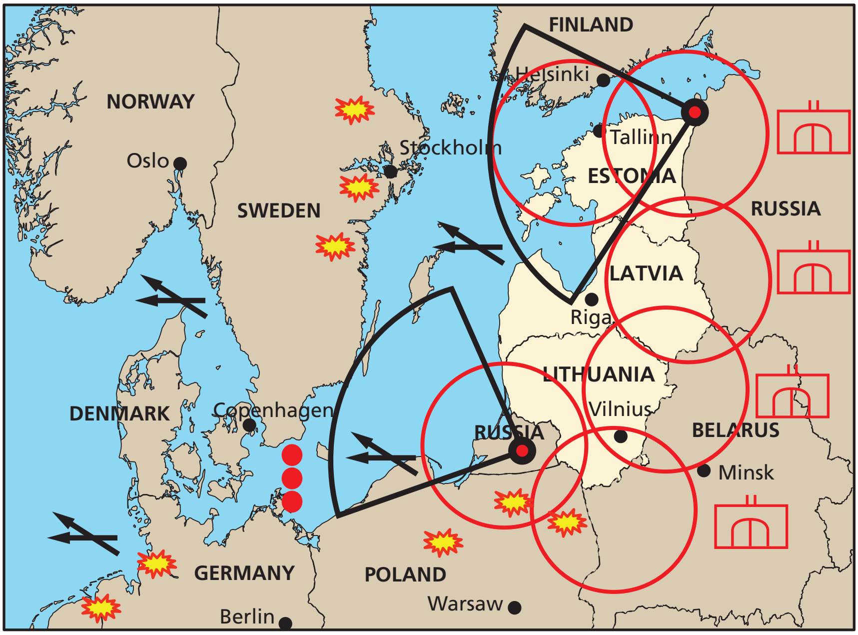
Figure 2.2
Russian Operational Plan and NATO Defense



SOURCE: Shlapak and Johnson, 2016b.
RAND *RR2124-2.2*

muster reinforcements and the two sides potentially negotiated an end to the conflict. An illustration of the status of the battle at that point is shown in Figure 2.4.

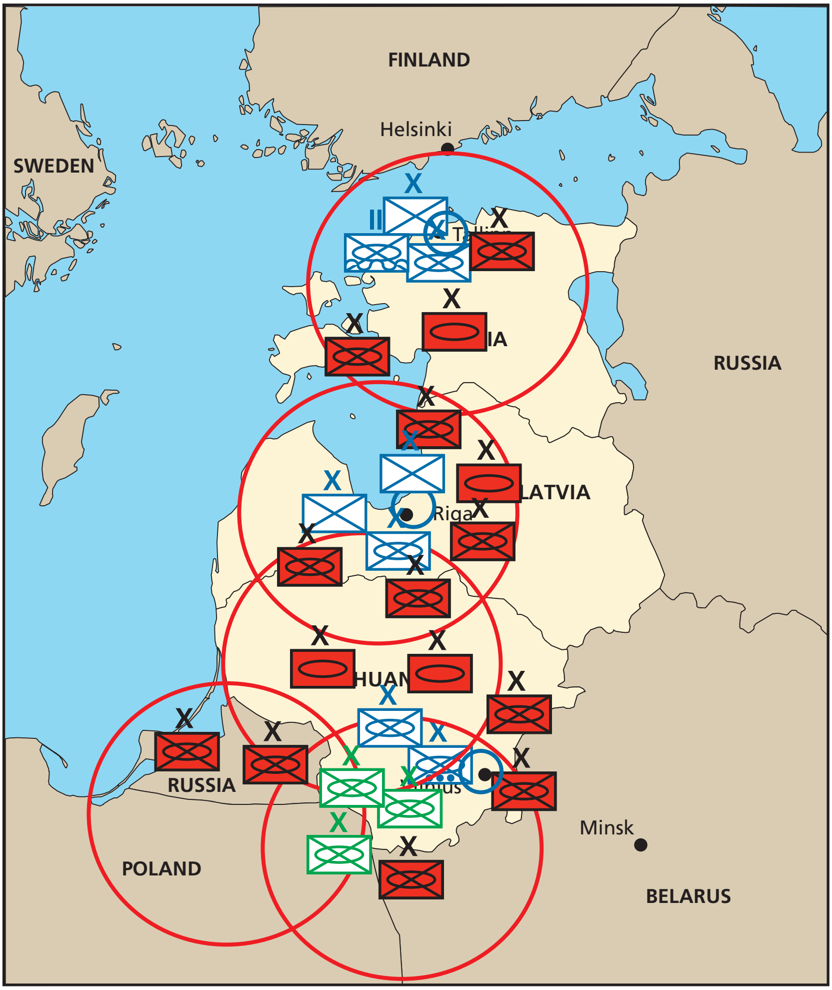
Figure 2.3
Russian A2AD/Sensor-Strike Concept



SOURCE: Shlapak and Johnson, 2016b.
RAND *RR2124-2.3*

The outcome in this scenario would be sufficient to deny Russia its objectives of isolating the Baltic states and inflicting a strategic defeat on NATO. But NATO forces would likely not be capable of defeating the Russians, at least in the first phase of the battle. Indeed, the fate of the Baltic states would remain uncertain, depending on tactical combat outcomes and the ability of NATO to muster sufficient forces to drive the Russians out before they could defeat the NATO forces they had surrounded in Riga and Tallinn. Finally, even if ultimately successful, NATO forces would likely suffer unacceptably high losses in this scenario.

Figure 2.4
Status of Battle After Initial Ground Combat Phase



SOURCE: Shlapak and Johnson, 2016b.
RAND *RR2124-2.4*

Implications for Future Fires Capabilities

This scenario has important implications for future Army fires. One significant driver of the outcome is the current disparity between the United States/NATO and Russia in the Baltics with respect to long-range fires capabilities. NATO has to fight outnumbered and win under Russia's A2AD and fires systems that can deny NATO air superiority and sea control and inflict unacceptable losses on NATO forces. This imbalance is illustrated in Figure 2.5.

The figure shows that U.S. and NATO forces and assets can come under fire throughout the theater from Russian systems, such as the *Iskander* and the SS-N-27, with no system capable of responding beyond fixed-wing aircraft.[5] This problem is compounded by Russian long-range IADS, built around the SA-21 (along with Russian airpower), that can prevent NATO from using its airpower in a decisive way early in the conflict. Russian rockets and artillery also outrange their U.S./NATO counterparts and thus can threaten U.S./NATO ground forces while protecting Russian forces from what could be decisive U.S./NATO close combat capabilities. On top of these qualitative advantages, Russia has large numerical advantages in tubes and launchers that make this imbalance additionally problematic. Indeed, the density of U.S./NATO artillery in this scenario is significantly lower that what it was in Germany during the Cold War, resulting from the smaller number of tubes available and the greater frontage that U.S. forces will have to cover. The United States and NATO must find ways to destroy, neutralize, or protect against these Russian fires capabilities and gain systemic, positional, and force advantages to allow them to defeat the Russian ground forces and win the conflict.

Carrying out the envisioned operation and overcoming the Russian defensive system would require close coordination between NATO air and ground forces. Ground forces would have to maneuver within the envelope of friendly air cover and air support, and ground fires would have to play an integral role in suppressing Russian IADS.

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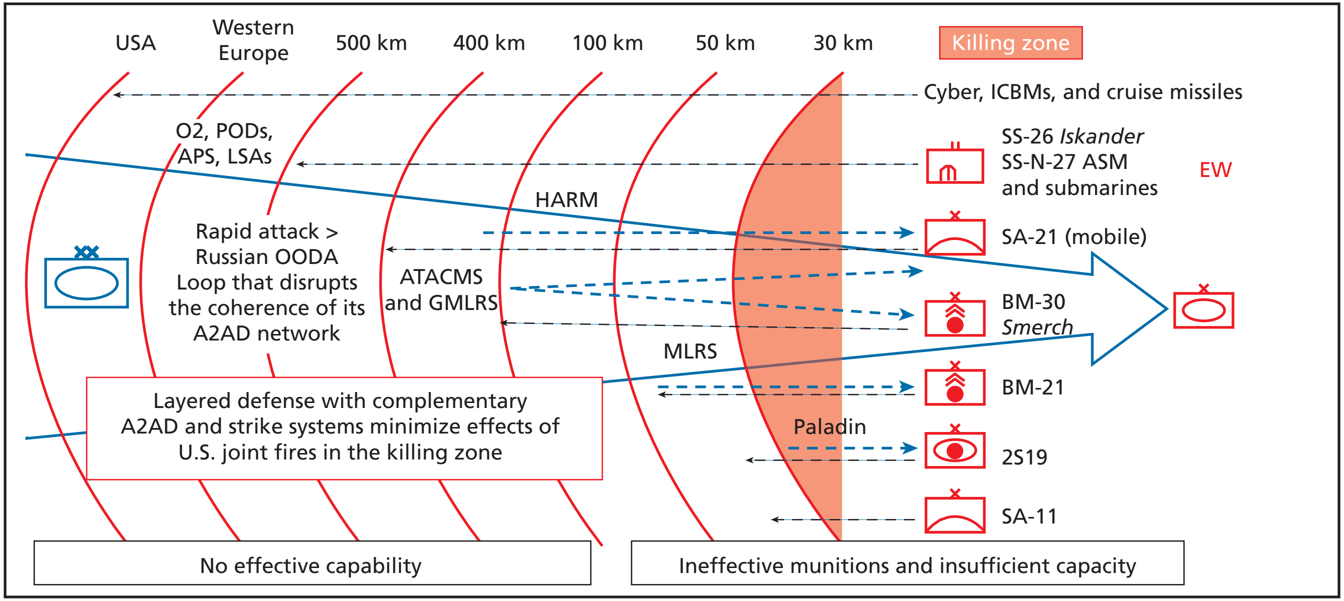
5 Attacking *Iskander* launch sites with aircraft could be problematic even if tactically feasible because they are located on Russian territory and the *Iskander* may also be seen as a potential nuclear delivery system.

Figure 2.5
Imbalance Between NATO and Russian Long-Range Fires Capabilities



SOURCE: Shlapak and Johnson, 2016b.
NOTES: ICBM = intercontinental ballistic missile; HARM = High-Speed Anti-Radar Missile; OODA = observe, orient, decide, and act; MLRS = Multiple Launch Rocket System; TACMS = Army Tactical Missile System.
RAND *RR2124-2.5*

Against a sophisticated adversary such as Russia, airpower must be employed from the outset of hostilities to enable land operations, and land power must be leveraged to enable air operations. The approach to defeating the Russian layered defenses may involve overcoming one layer at a time, akin to peeling an onion, or it may involve focused efforts at particular geographical locations and times to influence critical events during the battle.

While relevant to more than just fires, carrying out this operation would also require a NATO command structure able to plan and execute a complex, fast-moving, highly fluid air-land campaign. This cannot be improvised; it would require careful preparation. Tactical and operational schemes of maneuver should be developed and rehearsed; logistics support planned; and the reception, staging, and onward integration of reinforcing forces planned and exercised sufficiently to lend confidence that operations could be conducted when necessary. A U.S. Army corps headquarters in Europe could carry out such operational and support planning. An Army division headquarters, including the Divisional Artillery headquarters, for fires planning and coordination, could orchestrate the initial tactical fight in the Baltics. Additional U.S. or NATO headquarters could plan follow-on reinforcing operations.

Summary—Challenges for U.S. Army Artillery

The foregoing discussion has shown that U.S. ground fires forces would face the following fundamental challenges in a potential future conflict in Europe with Russia:

- U.S. artillery systems are largely outranged by Russian systems, especially in the area of cannons.
- U.S. artillery will probably be significantly outnumbered by their Russian counterparts.
- U.S. artillery may face a significant counterfire threat because of the range and numbers issues mentioned above, and because of Russian targeting capabilities in the Baltic region.

- Coordination of joint fires (artillery, air, aviation) will be a complex problem that will require significant advance planning and intelligence analysis.
- U.S. artillery and other fires capabilities are reliant on target systems that evolved to support COIN operations and may not be reliable sources of targeting data when facing adversaries with capable IADS, EW, and cyber capabilities.
- U.S. artillery and other fires capabilities may not be able to focus as much as desired on supporting U.S./NATO ground forces because of the need to support NATO air forces through suppression of enemy air defenses (SEAD).
- U.S. artillery may not be prepared for the levels of ammunition expenditure that may be required when fighting a near-peer conventional opponent.
- U.S. artillery effectiveness may be reduced by the need to avoid/defend against attacks by Russian SOF (Spetsnaz) in NATO's rear area.
- Heavy equipment and ammunition would have to be prepositioned forward to allow U.S. artillery to deploy and participate in the conflict in a timely manner.

North Korea

Over 60 years after the end of the Korean War, many Asia-Pacific countries are seeking to achieve greater prosperity, establish regional norms, and strive for a stable military balance. The Democratic People's Republic of Korea (North Korea), however, remains closed and authoritarian. Its conventional forces and the provocations of the North Korean regime threaten peace and stability on the Korean Peninsula. Its long-range missile and WMD programs—particularly its pursuit of nuclear weapons—also threaten peace and stability throughout Northeast Asia and constitute a growing, direct threat to the United States.

There are two potential conflict scenarios involving North Korea that would have implications for future U.S. Army fires requirements. Either might be triggered by a political crisis in North Korea, such as a collapse in the North Korean government or an attempted military coup (Bennett, 2013a). In the first, well-known scenario, North Korean forces launch a massive attack into the Republic of Korea (ROK; South Korea) with the goal of defeating the South Korean and allied (including the U.S.) militaries and reunifying the peninsula under North Korean rule. In that case, U.S. Army artillery would support U.S. and South Korean forces in defeating the attack. South Korean and U.S. forces could then potentially conduct a counteroffensive into North Korea to defeat the North Korean armed forces. In the second scenario, without attempting to invade the South, the North Korean artillery emplaced just north of the demilitarized zone (DMZ) conduct an intensive bombardment of South Korean forces and the Seoul metropolitan area, with the goal of compelling action by the South Korean government, such as expelling U.S. forces from the peninsula or providing resources to North Korea. In that case, U.S. Army artillery, and other joint and ROK fires capabilities, would be called upon to quickly suppress or destroy the North Korean artillery. They would also support a potential South Korean/U.S. ground attack into North Korea with the aim of occupying the North Korean firing positions and preventing a recurrence of the bombardment.

Theater Geography

A conflict on the Korean Peninsula would take place predominantly across the 240-km long DMZ, which snakes across the middle of the peninsula roughly from east to west (Figure 2.6). The DMZ itself is about 4 km wide, but the areas just to the north and south contain large military forces from North and South Korea and are very heavily fortified. South Korea's capital and largest city, Seoul, with a metropolitan area population of about 25 million, is located only approximately 55 km south of the DMZ. In the North, the capital, Pyongyang, is approximately 140 km north of the DMZ. Because the military standoff has existed since the Korean War, distances from the DMZ to the numerous bases supporting forces on both sides are fairly short. U.S. Army bases, Camps Casey, Hovey, Red Cloud, and Stanley, are located north of Seoul. Yongsan Garrison and the K16 airfield are located in Seoul. Osan and Kunsan Air Force Bases are located 64 and 240 km

Figure 2.6
The Korean Peninsula

RAND *RR2124-2.6*

south of Seoul, respectively. The United States also maintains airbases in Japan (Misawa, Yokota, Kadena, Iwakuni, and Futenma) that could provide support in a Korean conflict.

The terrain in central Korea is mountainous, particularly in the east. There are a few large passes and a limited road network that would allow passage of large armored or mechanized forces from north to south. The terrain becomes somewhat less severe on the west side of the peninsula, between the DMZ and Pyongyang and northward along the coast. The remainder of North Korea, to the east and north of Pyongyang, is mountainous and rural, also with a limited road network. The area in South Korea between just south of the DMZ and Seoul is heavily developed. In North Korea, Pyongyang is by far the largest city, with a population of 3.2 million and a large built-up footprint. Chongjin and Hamhung, on the east coast, have populations of 670,000 and 770,000, respectively. The approximately two dozen other major cities in North Korea have populations between 100,000 and 400,000 and are located mostly in the western part of the country or along the east coast.

The restrictive terrain in Korea (ranging from small hills to mountains, villages to major urban areas, numerous narrow valleys, and flooded rice paddies in the flat areas during the growing season) would have a major effect on ground maneuver as well as fires. The need for field artillery fires to hit enemy positions on the reverse slopes of hills and mountains would be significant in this scenario. Congestion along narrow maneuver corridors would certainly influence ground maneuver, which would in turn influence how field artillery units would support U.S. and ROK infantry and armor.

First Conflict—North Korean Invasion of South Korea

It is assumed that this conflict would occur after a political crisis, which would provide perhaps a short warning that would induce North Korea to launch what would be a desperate attempt to defeat South Korea and reunify the peninsula under its rule. North Korea possesses a large army, supported by plentiful artillery, chemical weapons, and even nuclear and biological weapons. But its military equipment is mostly obsolescent. Its soldiers lack training and are in poor condition, arising from North Korea's degraded food supply and health care system. Nevertheless, even with outdated weaponry and malnourished forces, the North Korean military could cause considerable damage to the ROK and supporting U.S. forces in a major conflict. In this scenario, South Korea and the United States are postulated to respond to the unprovoked North Korean attack by launching a counteroffensive after the attack is halted to defeat the North Korean military decisively (Bennett, 2013b).[6]

The North Korean Army consists of 16 corps (comprising 81 divisions): nine infantry, four mechanized, one armored, and one artillery.[7] Five infantry, four mechanized, the armored, and the artillery corps are deployed on or close to the DMZ. Five others are deployed within 150 km of the DMZ, along major north-south lines of communication that would provide rapid access to avenues of approach into South Korea (Office of the Secretary of Defense, 2013). The army has about 14,000 artillery pieces and rocket launchers, about 8,000 of which are located within 160 km of the DMZ, in protected underground shelters (Republic of Korea, Ministry of Defense, 2015; Bonds, Johnson, and Steinberg, 2015). North Korea possesses large stocks of chemical agents, between 2,500 and 5,000 tons, that could fill hundreds of thousands of chemical shells and rockets. U.S. commanders believe that North Korea could use chemical weapons during a conflict without restraint (Bennett, 2013b). The North Korean Air Force operates about 600 combat aircraft (roughly eight wings equivalent), primarily Soviet models dating from the 1980s back to the 1950s ("World Air Forces 2016," 2015; Office of the Secretary of Defense, 2013). North Korea possesses a dense air defense system of older SA-2, SA-3, and SA-5 SAMs, mobile SA-13 SAMs, mobile and fixed anti-aircraft artillery, and numerous older man-portable air defense systems (MANPADS), such as the SA-7. The North Korean Navy possesses 430 aging

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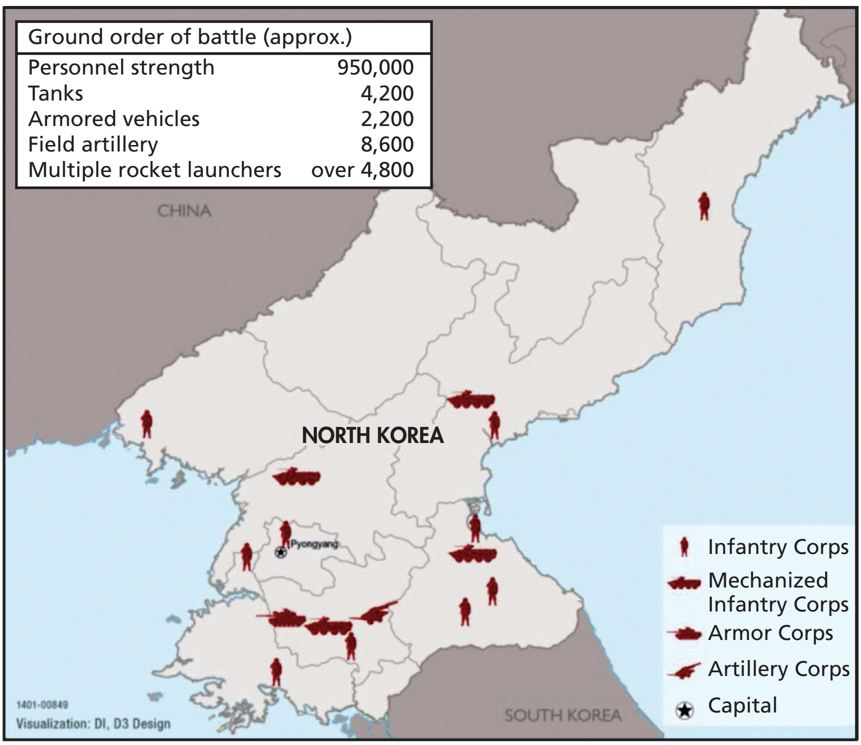
[6] In such a case, it is understood that China might intervene to manage the flow of refugees from North Korea, but it is assumed that no conflict between China and South Korean/U.S. forces would occur.

[7] Demographic pressures could cause North Korea to reduce the size of its armed forces in the future (Bennett, 2013b).

patrol craft but also 70 submarines and landing craft. North Korea possesses a large and relatively well-provisioned special operations force of 200,000 men that could be used to launch attacks into South Korea by land, air, or sea. Finally, North Korean operations would also be supported by cyber attacks. North Korean ground forces are shown in Figure 2.7. North Korean air forces are shown in Table 2.5.

The North Korean operational plan would be to attack southward from the Kaesong area toward Seoul with an armored and a mechanized corps. A mechanized corps would make a secondary thrust southward from Chorwon in the direction of Uijongbu, and two pin-

Figure 2.7
North Korean Ground Forces



SOURCE: Office of the Secretary of Defense, 2013, p. 16.

RAND *RR2124-2.7*

Table 2.5
North Korean Air Forces

Type	Aircraft
Shenyang F-5	106
Shenyang J-6	97
Chengdu J-7/MiG-21	146
MiG-23	56
MiG-29	35
Su-7	18
Su-25	34
Il-28	80
Total	598

SOURCE: International Institute for Strategic Studies, 2016.

ning attacks would be made by infantry corps, from the Chorwon area in the direction of Chunchon and along the eastern coast.

The forces that would be defending South Korea and conducting the counteroffensive into the North would consist of the South Korean military plus U.S. forces in Korea and U.S. forces outside Korea committed to the conflict. The South Korean Army today possesses 22 active duty divisions (6 mechanized and 16 infantry), but future force structure plans could reduce that to as few as 14 (plus 14 in reserve) by the early 2020s (Bennett, 2015). It also currently possesses four armored brigades, eight artillery brigades and one artillery group, two aviation brigades and six aviation groups, and six special forces brigades. The South Korean Air Force currently possesses nine fighter wings, flying F-4, F-5, F-15, F-16, and FA-50 aircraft. In the future it will be acquiring the F-35 and retiring the F-4 and F-5 (Waldron, 2013). The South Korean Navy possesses 130 ships, including guided missile destroyers and smaller classes, and 15 submarines. Combat forces in U.S. Forces Korea consist of the 2nd Infantry Division (one ABCT, one CAB, one FAB), and the 8th and the 51st Fighter Wings, flying F-16 and A-10 aircraft. U.S. Air Force combat units in Japan include the 35th Fighter Wing (F-16s) and the 18th Wing (F-15s). One U.S. Marine Corps squadron (F/A-18s) is also based in Japan. U.S. Navy forces in the region include the 7th Fleet, based in Japan, with a carrier strike group, amphibious assault forces, anti-submarine warfare and maritime patrol aircraft, and other supporting naval forces. South Korean and U.S. forces would also be supported by SOF, ISR, cyber, and EW capabilities.

After the onset of the political crisis that is postulated to lead to war, and upon observing North Korean preparations for the attack, U.S. forces could begin to flow to the Korean theater to bolster the defense and participate in the counteroffensive. Given anticipated future force structure and the need to maintain forces for operations and contingencies elsewhere in the world, it is postulated that four additional Army divisions (each with three BCTs, one CAB, and one FAB) and one Marine Expeditionary Force would be committed to the conflict (Bennett, 2013b).[8] Similarly, it is postulated that five additional Air Force fighter wings and two bomber wings would be committed, along with three additional U.S. Navy carrier strike groups. ROK/U.S. ground forces are shown in Table 2.6; air forces in Table 2.7.

At the beginning of the battle, North Korean artillery would bombard South Korean positions along the DMZ. They might also fire into the Seoul metropolitan area to create civilian panic. North Korean land-attack cruise missiles and short-range ballistic missiles would attack South Korean/U.S. airbases to destroy aircraft on the ground and prohibit air operations. North Korean missile attacks on ROK airbases and ports, as well as artillery attacks on forward forces, could employ chemical weapons. The North Korean Air Force might try to support these initial strikes, although its capabilities against South Korean/U.S. air defenses would be limited. The North Korean Navy would try to attack ROK ships and disrupt port operations. It might also attempt to insert SOF along the South Korean coasts. North Korean SOF would also try to infiltrate into South Korea across

[8] Ongoing contingencies in other parts of the world would reduce the number of ready formations available for prompt deployment to Korea.

Table 2.6
U.S. and South Korean Ground Forces (brigade equivalent), North Korea Scenario

Country	Type	Quantity
South Korea	Armored	4
	Mechanized infantry	18
	Infantry (on the DMZ)	12
United States (following deployment)	Armored	6
	Mechanized infantry	6
	Motorized infantry	9
South Korea	Artillery	16
United States	Artillery	6
South Korea	Aviation	4
United States	Aviation	6
Total		87

SOURCE: International Institute for Strategic Studies, 2016.

the DMZ and under it via tunnel. North Korean cyber attacks would attempt to degrade ROK/U.S. operations (Farley, 2015).

The initial ground attack would be conducted mostly by North Korean infantry, potentially with the North Korean armored corps attempting to break through South Korean defenses in one sector, such as that just north of Seoul. The two mechanized infantry corps would attempt to reinforce any successful initial attacks. Because of the favorable and heavily fortified defensive terrain and the disparities in equipment quality and training between the North Korean and South Korean forces, it is envisioned that the North Korean ground offensive would be halted without great gains. Nevertheless, South Korean ground forces would suffer losses and South Korean infrastructure would suffer damage from artillery and potentially SOF attacks. U.S. forces would contribute in this first phase of the battle by suppressing North Korean artillery, blunting any North Korean armored thrusts, and neutralizing North Korean air forces and missile systems

Table 2.7
U.S. and South Korean Air Forces, North Korea Scenario

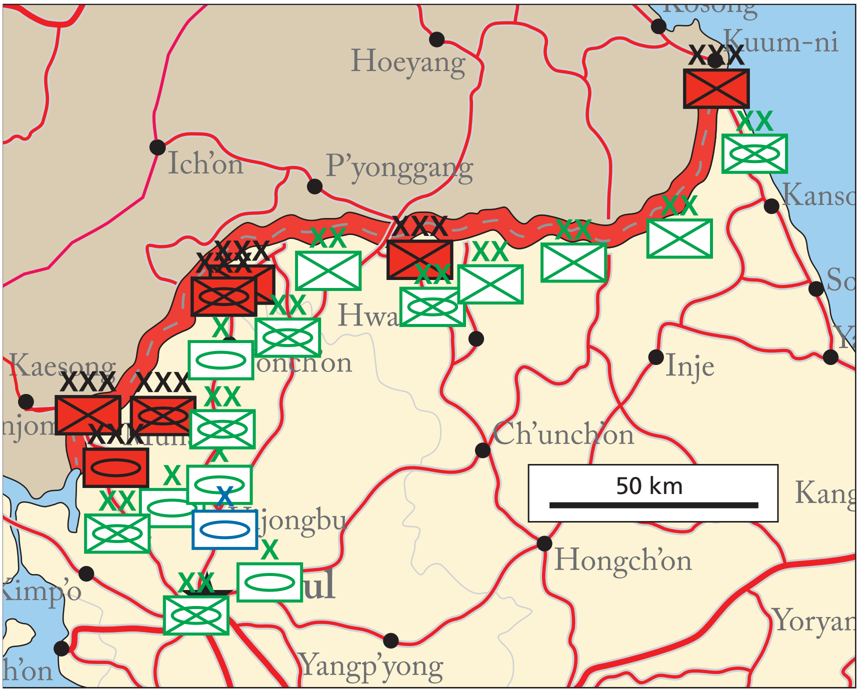
Country	Type	Aircraft
United States	F-15C	48
	F-15E	48
	F-16	168
	F-22	40
	F-35	120
	F/A-18	228
	B-1	32
	B-2	10
South Korea	F-15K	59
	F-16	169
	FA-50	60
	F-35	40
	Total	1,026

SOURCE: International Institute for Strategic Studies, 2016.

(including those capable of delivering WMD). An illustration of the first phase of the ground battle is shown in Figure 2.8.

After the North Korean offensive was halted, it is postulated that South Korea and the United States would launch a counteroffensive into North Korea with the aim of defeating North Korean armed forces (Bennett, 2015). To prepare for the counteroffensive, South Korea and the United States would build up the ground forces needed to carry it out. The United States would also likely deploy additional anti-ballistic missile systems, such as Terminal High-Altitude Area Defense (THAAD), Patriot, and Aegis, to defend against potential North Korean attacks. While doing so, South Korean and U.S. air forces, supplemented by ground and naval fires, would attack North

Figure 2.8
Status of Battle After Initial Ground Combat Phase



RAND *RR2124-2.8*

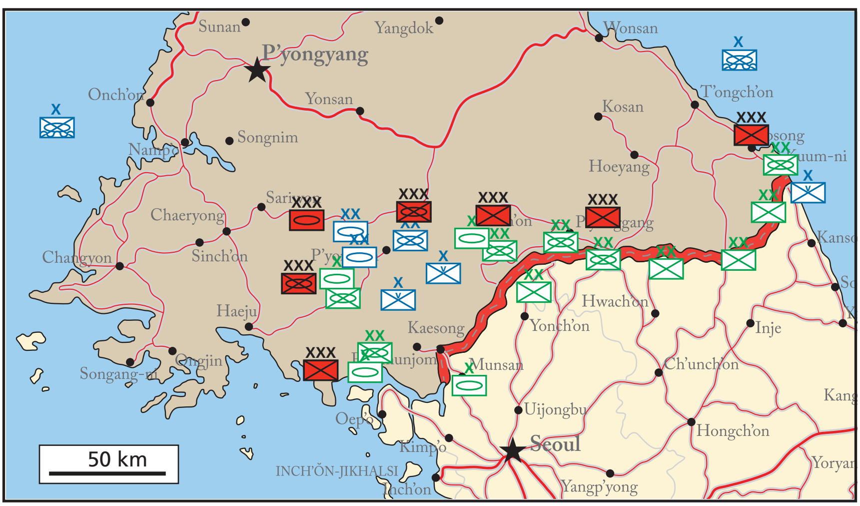
Korean ground forces, WMD delivery assets, and North Korean military infrastructure. This interlude could be several weeks—sufficient time for U.S. heavy forces to arrive from outside the theater.

After building up forces and conducting the air campaign to reduce the North Korean defenses and neutralize their WMD delivery capabilities, South Korean and U.S. forces would launch their counter-offensive. The attack would be led by South Korean and U.S. armored forces. The principal avenues of advance would likely run along the roads from Kaesong, just north of the DMZ in the west, toward Pyongyang, with a potential parallel avenue farther east, from Yeoncheon to Chorwon and then northward toward Pyongyang. A secondary avenue of advance could run along the road on the North Korean east coast.

U.S. Marine Corps and South Korean Marine amphibious forces could also make landings along both North Korean coasts to create defensive dilemmas for North Korean forces and cut off their withdrawal in the face of the main allied ground thrusts. The goal of the allied attacks would be to defeat the North Korean armed forces in detail. One potential course of the allied offensive is depicted in Figure 2.9.

One significant risk allied forces would face in the attack would be North Korean use of WMD, including nuclear weapons, once the regime realized the intent of the allied offensive. Thus, over the course of the attack, allied forces would make special efforts to neutralize and capture the 200 to 300 WMD production and delivery sites in North Korea. The United States would also make clear that its nuclear umbrella remained in place over Korea and it could potentially respond to any North Korean nuclear use. Another risk to be managed would be the potential intervention of China, at a minimum to handle the large number of North Korean refugees that would likely flee northward once they realized that the North Korean military was being defeated.

Figure 2.9
Potential Development of Allied Counteroffensive into North Korea



RAND *RR2124-2.9*

Second Conflict—North Korean Artillery Bombardment of South Korea

In this scenario, instead of launching an invasion of the South, which would likely lead to a military defeat after a ROK/U.S. counteroffensive, North Korea commences an intensive artillery bombardment of South Korean forces and the greater Seoul metropolitan area from the vicinity of the Kaesong Heights region just across the DMZ. Its goal would be to force political concessions from the South Korean government, such as the expulsion of U.S. forces from the peninsula or an agreement to provide resources to the North that were needed to prop up the failing regime. In response, South Korea and the United States would attempt to quickly neutralize the North Korean artillery and in this specific case they are postulated to launch a counterattack into the Kaesong Heights to occupy the North Korean firing positions. This scenario might be seen as a larger and more intensive analogue to the North Korean shelling of Yeonpyeong Island in 2010 but with a commensurate South Korean/U.S. response (Bennett, 2015).

The North Korean forces in this scenario would be the same as in the first, but those conducting the attack would be the North Korean artillery on or around the Kaesong Heights, potentially 3,000 individual pieces firing from fortified positions. North Korean ground forces in the area would consist of an armored, two mechanized, and an infantry corps, although they would be defending their positions in place. North Korean air and naval forces and SOF would be the same as in the first scenario. The air forces and SOF might participate in attacks on the Seoul metropolitan area. They would otherwise act to defend North Korea. North Korean ground forces participating in this conflict are shown in Table 2.8. North Korean air forces were shown in Table 2.5.

South Korean forces present would be the same as those in the first scenario. Ground forces to be used in the counterattack into the Kaesong Heights would consist of three mechanized divisions, three armored brigades, and six independent artillery brigades. U.S. forces would be those in northeast Asia at the beginning of the conflict plus those that could be moved into the theater quickly so as to be used to halt the bombardment as soon as possible. U.S. ground forces would

Table 2.8
North Korean Ground Forces, Second Conflict

Unit/System	Quantity
Infantry corps	1
Mechanized corps	2
Armored corps	1
Artillery corps	1
Personnel	~340,000
Tanks	~2,800
Armored vehicles	~1,900
Field artillery	~1,800
Rocket launchers	~1,000

SOURCE: International Institute for Strategic Studies, 2016.

consist of the 2nd Infantry Division (one ABCT, one FAB, one CAB), plus one ABCT (constituted using prepositioned equipment), one FAB, and one Marine Expeditionary Brigade deployed to the theater. U.S. air forces would consist of the four fighter wings in theater plus five additional fighter and bomber wings. U.S. naval forces would consist of the one carrier strike group present plus two others deployed. ROK and U.S. ground and air forces participating in the conflict are listed in Tables 2.9 and 2.10.

It is envisioned that the immediate allied response to the North Korean bombardment would be to try to neutralize the North Korean artillery with ROK and U.S. artillery counterfires. ROK and U.S. air forces would eliminate the North Korean air threat and then also work to neutralize the North Korean artillery. After some period of time, when that turned out to be insufficient to stop the bombardment, ROK and U.S. ground forces would drive northward onto the Kaesong Heights. ROK and U.S. artillery would provide fire support for that attack, but heavy ground fighting would be required to overcome

Table 2.9
U.S. and South Korean Ground Forces (brigade equivalent), Second Conflict

Country	Type	Quantity
South Korea	Armored	3
	Mechanized infantry	9
	Infantry	–
United States	Armored	2
	Mechanized infantry	1
	Motorized infantry	–
South Korea	Artillery	9
United States	Artillery	2
South Korea	Aviation	2
United States	Aviation	1
Total		29

SOURCE: International Institute for Strategic Studies, 2016.

dug-in North Korean ground forces and achieve the allied objective. The allied attack is depicted in Figure 2.10.

Implications for Future Fires Capabilities

These Korea scenarios also have important implications for future Army fires capabilities. First, U.S. and South Korean artillery would likely be greatly outnumbered by North Korean tubes and launchers. North Korea has approximately 14,000 artillery pieces, about 8,000 of which are deployed within 160 km of the DMZ. By contrast, the South Korean and U.S. forces expected to participate in a general Korean conflict would possess only about 6,400 tubes and launchers (Republic of Korea, Ministry of National Defense, 2015, p. 47 [5,800 tubes and launchers]; Field Manual 3-09, 2014). North Korea also possesses long-range systems that would be particularly threatening in the Kaesong Heights scenario: 170mm self-propelled guns and 240mm MRLs, with

Table 2.10
U.S. and South Korean Air Forces, Second Conflict

Country	Type	Aircraft
United States	F-15C	48
	F-15E	–
	F-16	168
	F-22	40
	F-35	72
	F/A-18	180
	B-1	32
	B-2	10
South Korea	F-15K	59
	F-16	169
	FA-50	60
	F-35	40
	Total	878

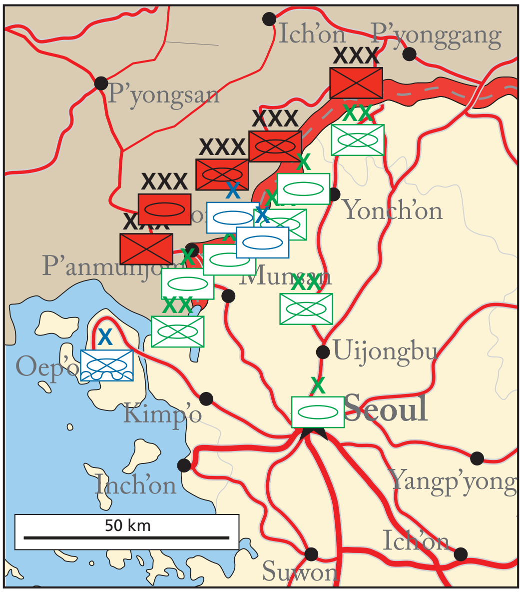
SOURCE: International Institute for Strategic Studies, 2016.

a 300mm MRL currently under development that could potentially reach central South Korea (Republic of Korea, Ministry of National Defense, 2015, p. 28). North Korean artillery is also emplaced in heavy fortifications along the DMZ such that it cannot be neutralized without very accurate counterfires. This would create a large demand for precision-guided munitions for ROK and U.S. artillery and air forces.[9]

Although North Korea may not be able to conduct precise fires as well as ROK and U.S. artillery, the North Korean numerical advan-

9 Currently planned inventories of U.S. and ROK precision artillery munitions may not be sufficient to meet demands. ROK artillery may also require more precise targeting to support counterfire against North Korean fortified emplacements (U.S. Army Fires Center of Excellence, discussions, May 5, 2016).

Figure 2.10
ROK/U.S. Attack onto Kaesong Heights



RAND *RR2124-2.10*

tage, the long range of some North Korean artillery systems, and their emplacement in fortified positions could allow North Korea to conduct significant counterfires against the ROK/United States. Those counterfires could be made more threatening by North Korea's use of chemical weapons. In the worst case, if the North Korean regime felt threatened, it could use nuclear weapons against ROK or U.S. forces, although the means of delivery (missile, artillery, atomic demolition) that might be used in 2025 and beyond and the likelihood of the weapons' use against troops in the field, as opposed to other targets, is not entirely certain. North Korea's possession and potential use of WMD could also require that U.S. artillery be prepared to attack WMD targets on very short notice, and potentially at long range, to prevent their use.

In both Korean scenarios, U.S. Army artillery would be called upon to attack North Korean forces, either those attacking southward in the first scenario or those defending against allied counterattacks in both scenarios. Because North Korea possesses sizable armored and mechanized forces, there would be a demand for U.S. fires against armored vehicle targets. For those fires to be most effective, Army artillery would need an adequate supply of anti-armor munitions.

Finally, for Army artillery to play a more significant role in a Korean conflict, artillery systems and ammunition would have to be prepositioned in Korea or at least in northeast Asia. Today, one FAB is stationed in South Korea. U.S. Army artillery constitutes about 10 percent of the total U.S./ROK tubes in South Korea. This is a smaller fraction than what it was during the Cold War. U.S. Army artillery contribution to U.S./ROK combat power in the future will result more from the qualities of U.S. artillery than sheer numbers. While it might be envisioned that U.S. heavy forces, including more artillery, would be deployed from the continental United States to Korea in the event of a general Korean conflict, those forces would likely not be available in time to participate in the initial defense of South Korea. They also would not be available to participate in a quick ROK/U.S. counterattack into North Korea in a Kaesong Heights–like scenario.

Summary—Challenges for U.S. Army Artillery

The foregoing discussion has shown that U.S. Army artillery would face the following fundamental challenges in potential future conflicts with North Korea:

- U.S. and South Korean artillery may be significantly outnumbered by North Korean fires forces.
- Neutralizing North Korean artillery with counterfires may be difficult because of their fortified emplacements; South Korean artillery needs more precise targeting and precision munitions.
- Due to the ability of North Korean cannons and rocket launchers to fire and rapidly return to underground fortifications, U.S. and ROK artillery counterfire would have to be highly responsive with the ability to acquire and engage the North's artillery in very short amounts of time.
-

- U.S. artillery may face counterfires using chemical or potentially even nuclear weapons.
- U.S. artillery may have to target and attack North Korean WMD capabilities (artillery and missiles) very quickly and at long ranges to prevent their further use.
- U.S. artillery may not be prepared for the levels of ammunition expenditure that may be required when fighting a near-peer conventional opponent.
- U.S. artillery effectiveness may be reduced by the need to avoid/defend against attacks by North Korean SOF in rear areas.
- Deploying additional artillery heavy equipment and ammunition to be used to support a counteroffensive into North Korea could delay the counteroffensive.

Iran

The potential for conflict endures in the Middle East because of religious differences, historical animosities between regional states, and popular dissatisfaction with regional governments. Competition for resources, including energy and water, will increase risk and could escalate or broaden future conflicts. Iran remains a destabilizing actor in the region because of its hostility to U.S. partners and allies, its attempts to control or destabilize regional governments, its participation in regional conflicts, and its support of international terrorism. While the recent agreement on Iran's nuclear program reduces the risk of conflict and may portend a reduction of tensions in the future, in the near-to-mid term, Iran will likely continue to pose a threat to U.S. interests in the Middle East.

The potential scenario involving Iran evaluated in this report that would have implications for future U.S. Army fires requirements is a military response to an Iranian closure of the Strait of Hormuz. It is postulated that, during a political crisis, Iran fires on merchant ships and warships attempting to protect the merchant traffic passing through the Strait. U.S. and, potentially, allied forces would conduct strike operations against targets in Iran to coerce the regime to reopen the Strait. Forced entry operations would be conducted to secure key islands in the Persian Gulf and the Strait of Hormuz. When that proved unsuccessful after several weeks of attacks, raids would potentially be conducted to clear areas in southern Iran that were being used as launch sites for long-range, anti-ship cruise missiles or to disrupt the operations of Iranian small attack craft. Army artillery could potentially participate in strike operations (including preliminary SEAD) and support the forced entry operations and raids using long-range rockets from the south shore of the Gulf and Strait. Army artillery could potentially participate in forced entry operations and raids in conjunction with other U.S./allied ground forces.

Theater Geography

The geography in this scenario is dominated by the Strait of Hormuz, connecting the Persian Gulf and the Gulf of Oman, which lie between Iran, to the north, and the Gulf States of Saudi Arabia, Qatar, the United Arab Emirates, and Oman, to the south (Figure 2.11). The distance across the narrowest part of the Strait, from the small portion of Oman (the Musandam Governorate) at the tip of the Musandam Peninsula, to the islands of Qeshm and Larak, and Hengam Island, is about 60 to 80 km. The distance to Bandar Abbas, on the Iranian shore, is 120 km. Distances from the United Arab Emirates and the remainder of Oman, across the Persian Gulf and Gulf of Oman, respectively, to the Iranian shore are between 110 and 240 km; from Qatar to the Iranian shore is roughly 240 km.

Iran also possesses islands and oil platforms in the Gulf and Strait. It can and does place military forces on them (see Figure 2.12) that would likely be used in any attempt to close the Strait.

Support for U.S. operations would be facilitated by the bases in the Persian Gulf region that the United States has been using for years. Bases of different sizes, operated by U.S. military services or with a U.S. military presence, are located in each of the Gulf States (DoD, 2014b).

Figure 2.11
Iran and the Strait of Hormuz

RAND *RR2124-2.6*

The Conflict

The Iranian regular armed forces consist of the Islamic Republic of Iran Army, Navy, Air Force, and Air Defense Force. The Army of the Guardians of the Islamic Revolution, or Islamic Revolutionary Guards Corps (IRGC), is a separate but smaller military organization, with four branches: the Navy, Aerospace Force, Ground Forces, and the Quds Force (special forces). The Basij is a large paramilitary volunteer force controlled by the IRGC. The Iranian Army possesses four armored divisions, six infantry divisions (with two potentially mechanized), two airborne/commando divisions, and approximately a dozen separate brigades, half of which are artillery ("Iranian Army Order of Battle," 2013).[10] The Iranian Air Force operates a mixture of approximately 170 combat aircraft of 1960s to 1980s vintages (see Table 2.11) (Cenciotti, 2014; "World Air Forces 2016," 2015). The Iranian Navy and IRGC naval forces are assumed to possess, by 2025, 12 frigates and corvettes, six submarines, and about 160 patrol and small attack craft.

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10 Iran may be transitioning to a brigade-centric model for its Army, with divisions being broken down into and operating as independent brigades ("Iran's Disappearing Divisions," 2012).

Figure 2.12
Persian Gulf Region, Iranian Naval Bases, and Reach of Anti-Ship Missiles

RAND *RR2124-2.12*

The Iran maintains several bases near the Strait of Hormuz, including headquarters at Bandar Abbas (Connell, 2013). It also possesses long-range ASMs, including the Chinese C-802 and HY-2 "Silkworm," emplaced on the Iranian coast around the Strait.

In this scenario, it is postulated that ground combat would be limited to forced entry operations to secure key islands in the Gulf and the Strait and potential raids to clear areas along the Iranian coast that were being used as missile launch sites or to support the operation of Iranian small attack craft. While Iran might deploy large ground forces around its major bases, such as Khorramshahr, Bushehr, Bandar Abbas, and Chah Bahar, the forces most likely to become involved in combat would be the small forces deployed around the approximately half dozen island bases, such as Abu Musa, Al-Farsiyah, Khark, Larak, Kharg Island, Qeshm, and Sirri, located in the Gulf and Strait (Cordes-

Table 2.11
Iranian Air Forces

Type	Aircraft
F-4	42
F-5/Saeqeh	25
F-14	24
Mirage F-1	9
Chengdu F-7	17
MiG-29	20
Su-24	24
Su-25	10
Total	171

SOURCE: International Institute for Strategic Studies, 2016.

man, 2007). Figure 2.12 shows the Persian Gulf region, the locations of Iranian naval bases, and the potential reach of Iranian ground-based ASMs (here, the C-802, with a range of 120 km) into the Gulf. To the reach of those missiles would be added the reach of those based on ships or boats operating from the Iranian bases.

The forces that would respond to the Iranian closure of the Strait of Hormuz would consist of U.S. forces based in the Gulf region, U.S. forces outside the region committed to the conflict, and potentially, allied forces, both from the region and not. The United States has based forces in the Persian Gulf for many years. Thus, for this scenario it is postulated that at the time the conflict breaks out, the United States would have one fighter wing based at one or more regional bases and prepositioned heavy equipment for Army forces located in the Gulf States. It would also have one carrier strike group in the Arabian Sea.[11] It is postulated that five additional Air Force fighter wings and two

[11] This assumes that Iran would wait to launch its attacks on shipping until no U.S. carrier strike group was located in the Persian Gulf.

bomber wings would be committed to the conflict, along with two additional U.S. Navy carrier strike groups. To secure the islands in the Gulf and Strait and threaten potential landings in Iran, one Marine Expeditionary Brigade would be deployed as well. On the ground, Army forces consisting of one ABCT, one IBCT, one FAB, and one CAB, would deploy to the Gulf and/or fall in on prepositioned equipment there U.S. forces would also be supported by SOF, ISR, cyber, and EW capabilities. U.S. ground forces are shown in Table 2.12; air forces in Table 2.13.

Because the conflict would directly threaten the Gulf States and would have international trade and economic consequences, forces from several allied nations, particularly air, naval, and long-range fires forces, might participate alongside the United States. Kuwait, Saudi Arabia, Qatar, the United Arab Emirates, and Oman could each potentially commit one or more combat squadrons (and Saudi Arabia one or more wings) to the conflict. Certain Gulf allies possess the High-Mobility Artillery Rocket System (HIMARS) with ATACMS and could conduct fires across the Gulf against Iran. Allies from outside the region, such as Britain and France, could commit both naval and air forces.

Table 2.12
U.S. Ground Forces (brigade equivalent), Iran Scenario

Type	Quantity
Armored	1
Mechanized infantry	1
Infantry	1
Artillery	1
Aviation	1
Total	5

SOURCE: International Institute for Strategic Studies, 2016.

Table 2.13
U.S. Air Forces, Iran Scenario

Type	Aircraft
F-15C	24
F-15E	48
F-16	72
F-22	40
F-35	96
F/A-18	180
B-1	32
B-2	10
Total	502

SOURCE: International Institute for Strategic Studies, 2016.

It is envisioned that Iran would begin the conflict by attacking merchant ships and any warships attempting to protect the merchant traffic passing through the Strait and into the Gulf. It would use long-range ASMs where necessary and attacks by small craft where proximity allowed. It would also lay mines in the Strait. Iranian aircraft might attempt to launch strikes early in the conflict, although they would be vulnerable to interception by Gulf State and U.S. air forces based in the region. Iran could also attempt to insert SOF into the Gulf States, either during or before the conflict, to make further attacks on shipping and shipping facilities and disrupt allied military operations.

U.S. and potentially allied air forces would respond to the Iranian attacks by suppressing the somewhat limited Iranian air defenses and conducting strike operations to halt the attacks and coerce the regime to end the conflict. Strikes would focus on airbases (initially), missile launchers and their targeting capabilities, warships and small attack craft, and naval bases. The U.S. Navy, potentially with allied assistance, would conduct countermine operations in the Strait and the Gulf. Forced entry operations would be conducted by the Marine

Corps and potentially Army airmobile forces to secure key islands in the Persian Gulf and the Strait of Hormuz. If the allied attacks were insufficient to halt the Iranian attacks and end the conflict, after several weeks, raids would potentially be conducted by Marine Corps and Army airmobile forces to clear areas in southern Iran that were being used as missile launch sites or to disrupt Iranian small craft operations. Large-scale or long-duration land operations on the Iranian mainland would be avoided to avoid engagements with larger Iranian ground forces and to minimize political consequences. Throughout the allied response, Army artillery (and potentially allied artillery) could potentially participate in strike operations (including preliminary SEAD) and support the forced entry operations and raids using long-range missiles from the south shore of the Gulf/Strait. Army artillery (cannon and rocket/missile) could potentially participate in large raids in conjunction with other U.S./allied ground forces. Allied operations are illustrated in Figure 2.13.

Implications for Future Fires Capabilities

The Iran scenario has some important implications for future Army fires capabilities that are not necessarily evident from other scenarios. First, for Army artillery to participate in this conflict, artillery equipment and ammunition would have to be prepositioned in the theater, in Saudi Arabia, Kuwait, or the Gulf States. The United States and its allies would seek to respond to the Iranian attacks very quickly to restore the free flow of commerce. Prepositioning (presuming that Army artillery would not be stationed in or rotated to the Gulf) would be necessary to allow the artillery to participate in that response.

Since almost all of the ground-based fires in this scenario would be conducted from the south shore of the Persian Gulf or Strait of Hormuz against targets on islands or the north shore, they would have to be conducted by long-range systems such as ATACMS (or possibly the extended-range Guided Multiple-Launch Rocket System [GMLRS]). This would require a sufficient supply of ammunition in the Gulf sufficient. Conducting such long-range fires would also require a long-range targeting capability. If fires were conducted against fleeting targets such as mobile missile launchers or even pier-side boats, the tar-

Figure 2.13
Allied Strait of Hormuz Operations Against Iran

RAND *RR2124-2.13*

geting capability and the command and control of the artillery would have to be sufficiently responsive for the fires to be effective.

Finally, several of the Gulf State nations (Bahrain, Qatar, Saudi Arabia, and the United Arab Emirates) possess or may possess by 2025 long-range missile systems such as ATACMS that they could use to conduct fires against Iranian targets. Currently, however, their targeting and command and control are not coordinated with U.S. forces. That could lead to instances where Gulf State fires disrupt U.S. operations or create political consequences that could jeopardize the United States' achievement of its strategic objectives. To minimize that risk, the United States should seek to coordinate with the Gulf State nations all of the military operations that would take place in such a conflict.

Summary—Challenges for U.S. Army Artillery

The foregoing discussion has shown that U.S. ground fires forces would face the following fundamental challenges in a potential future conflict in the Persian Gulf with Iran:

- Heavy equipment and ammunition would have to be prepositioned forward to allow U.S. artillery to deploy and participate in the conflict in a timely manner.
- Long-range missiles would be required in sufficient supply to allow support of strike operations and joint forcible entry operations from the south shore of the Persian Gulf/Strait of Hormuz.
- Conducting long-range fires across the Gulf/Strait against movable targets would require prompt, long-range, remote targeting capabilities.
- U.S. artillery effectiveness might be reduced by the need to avoid/defend against attacks by Iranian SOF in rear areas.
- Gulf States ground-based missile (e.g., ATACMS) targeting is not currently coordinated with U.S. forces targeting; uncoordinated fires could disrupt U.S. operations or create political consequences that could hinder U.S. achievement of its strategic objectives.

Iraq/ISIL

The worst current manifestation of the potential for conflict in the Middle East is ISIL's occupation of territory in Iraq and Syria and its conflicts with those states' governments, their international partners, and local groups, such as the Kurds and others fighting in the Syrian civil war. The United States and several of its international and regional partners are engaged in the campaign to degrade and ultimately defeat ISIL. ISIL may or may not persist into the mid-term future in Iraq and Syria in its current form. However, even if it does not, given the broad unrest seen in the region, a similar VEO could possibly emerge and pose a threat sufficient to warrant a military effort by the United States and partner nations to defeat it.

This scenario is of further interest because the application of military power against VEOs is very different than its application against state threats. In particular, fighting such organizations may involve prolonged campaigns in which control of escalation is more difficult and more important. VEOs can also develop rudimentary combined arms capabilities or obtain state assistance and escalate a conflict into "hybrid" warfare. Such conflicts increase ambiguity, complicate decisionmaking, and slow the coordination of effective responses.

This scenario assumes that, in our time frame of interest, ISIL does still exist in substantially its current form. It is postulated that after the Iraqi government has become destabilized, ISIL begins raiding northern Saudi Arabia and eastern Jordan in an attempt to stir up anti-government rebellions. In response, Jordan, Saudi Arabia, Egypt, and the United States form a coalition, led by the United States, to destroy ISIL. The coalition launches a counterattack into Syria and Iraq to finally eliminate ISIL's strongholds in those countries. Army artillery would participate in this scenario in support of the predominantly Arab ground attacks. Challenges would arise from the nature of a conflict with a VEO in and around populated areas and the integration of U.S. and Arab forces in the operation.

Theater Geography

This scenario takes place predominantly in Iraq and Syria (Figure 2.14). The areas occupied or postulated to be occupied by ISIL are generally characterized by towns and cities linked by a few major roads and separated by sparsely populated desert. The area within a few kilometers of the Euphrates River in eastern Syria and central Iraq is often vegetated and occupied by farms and villages. Syria south of Damascus (Daraa Governorate) is more densely populated, with a more well-developed road network (Izady, 2014). At the beginning of this scenario, ISIL holds the cities of Raqqa (population 178,000) and Deir ez Zour (population 243,000) and occupies part of Daraa Governorate (population about 1 million) in Syria. It occupies parts of Ramadi (population 375,000) and Fallujah (population about 300,000) in Iraq.

ISIL motorized forces and opposing coalition mechanized forces operating in eastern Syria and central Iraq would largely move along

Figure 2.14
Syria and Iraq

RAND *RR2124-2.14*

the roads connecting major towns and cities. Most distances between cities are such that they would require motor transport to traverse: Raqqa to Deir ez Zour, 120 km; Deir ez Zour to Haditha, 250 km; Haditha to Ramadi, 110 km; Ramadi to Fallujah, 45 km; Ramadi to the Jordanian border, 400 km. In Syria south of Damascus, by contrast, where the population and the road network are denser, Daraa Governorate is directly adjacent to the Jordanian border.

The Conflict

It is assumed that in our time frame, ISIL is a protostate that has been able to amass relatively significant military power: some 25,000–30,000 full-time fighters organized as military units of battalion and brigade size. ISIL also possesses an additional 10,000–20,000 part-time fighters who serve as militia in ISIL-controlled cities and towns. Its weapons include several dozen armored vehicles, rocket launchers and mortars, large numbers of anti-tank guided missiles and rocket-propelled grenades, 20mm–57mm anti-aircraft guns, several hundred SA-7, -14, -16, and -18 MANPADS, and a small number of radar-guided SAMs, such as SA-8s obtained from the Syrian Army.

It is postulated that the Syrian government has been focusing on destroying opposition groups in central and western Syria rather than ISIL. In Iraq, ISIL in the north and non-ISIL rebel groups in the south have destabilized the government, and its military is tied up in fighting around Baghdad. U.S. forces have also been withdrawn from Iraq. The scenario conflict would begin when ISIL begins raiding eastern Jordan and northern Saudi Arabia to foment anti-government rebellions there.

In response to ISIL's attacks, Jordan, Saudi Arabia, the United States, and Egypt (after requests by Jordan and Saudi Arabia) form a coalition, led by the United States, to destroy ISIL. Arab coalition forces include eight brigades of regular ground forces and five battalions of SOF, plus, potentially, tactical fighter squadrons from each nation. U.S. forces include one IBCT, one SBCT, one CAB, one FAB, a division headquarters, a corps headquarters (coalition joint task force), SOF, and three Air Force wings. These ground forces and the U.S. air forces are listed in Tables 2.14 and 2.15.

The coalition would conduct a three-pronged offensive into ISIL-held territory. Jordanian forces (two brigades) would push northward into Syria's Daraa and Quneitra provinces to clear the ISIL presence south of Damascus. They would be supported by one U.S. artillery battalion. Egyptian forces (three brigades) would enter Iraq from eastern Jordan, move to the Syrian border at Al-Qaim, and push up the Euphrates River Valley in eastern Syria toward Deir ez Zour and Raqqa. They would also be supported by one U.S. artillery battalion and the U.S. IBCT (airmobile) and the CAB, which would provide aviation combat support and potentially conduct airmobile operations to seize key terrain or trap fleeing ISIL fighters. Finally, Saudi forces (two brigades) would move from northern Saudi Arabia into Anbar province in Iraq and drive on Ramadi from the west. Iraqi forces, one brigade from the Counter-Terrorism Service, would push westward from Baghdad, link up with the Saudis at Ramadi, and drive up the Euphrates to

Table 2.14
Allied Ground Forces (brigade equivalent), Iraq/ISIL Scenario

Country	Type	Quantity
Egypt	Mechanized infantry	2
	Motorized infantry	1
Jordan	Mechanized infantry	1
	Motorized infantry	1
Saudi Arabia	Mechanized infantry	2
Iraq	Motorized infantry	1
United States	Mechanized infantry	1
	Motorized infantry	1
United States	Artillery	1
United States	Aviation	1
Total		12

SOURCE: International Institute for Strategic Studies, 2016.

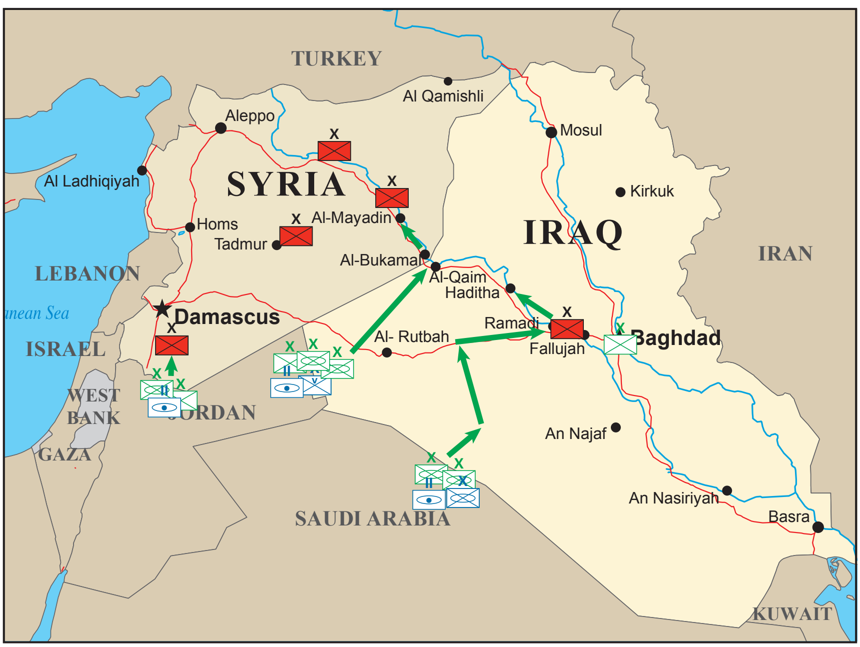
Table 2.15
U.S. Air Forces, Iraq/ISIL Scenario

Type	Aircraft
F-15E	15
F-16	60
F-35	20
B-1	10
Total	105

SOURCE: International Institute for Strategic Studies, 2016.

Haditha. The Saudis would be supported by one U.S. artillery battalion and the U.S. SBCT. U.S. forces would provide command, control, communications, computer, intelligence surveillance, and reconnaissance (C4ISR), fire support, attack and transport aviation, and fixed-wing support. The coalition goals would be to have the majority of the ground combat conducted by friendly Arab forces, minimize the amount of collateral damage and civilian casualties, and quickly overwhelm ISIL. It is envisioned that the operation could defeat the large ISIL military formations and drive its remaining fighters to ground in major cities in about 90 days. Eliminating ISIL's presence in major cities entirely would require longer-term operations, potentially much longer. U.S. forces, potentially in smaller numbers, could remain to support those operations. The coalition offensive is illustrated in Figure 2.15.

Figure 2.15
Coalition Offensive Against ISIL



RAND *RR2124-2.15*

Implications for Future Fires Capabilities

A potential coalition attack against ISIL also has some important implications for future Army fires capabilities. If Army artillery is to support a coalition of allies, U.S. fires (and U.S. forces generally) would need to be integrated in support of allied ground armies so that they would be effective. In this case, our coalition partners are nations with which we are not now training regularly. Thus, they probably would not be prepared to utilize U.S. fires capabilities. Rectifying this would require working with our prospective partners so that they gain some familiarity with Army capabilities and we gain more familiarity with their ground maneuver doctrines and capabilities. That could take some time before the offensive. It would also likely require the Army to provide targeting capabilities for the partners we would aim to support. This would require sufficient Army fires liaison teams, along with interpreters and communications equipment, to coordinate fire support down to the battalion level. This particular scenario would require about 30 such teams. Even with these steps taken, the lack of familiarity between the armies and the lack of technical capabilities like the ability to determine the locations of partner forces could require the use of procedural controls like operational phase lines and fire support coordination lines that would likely slow the pace of coalition operations.

Because fighting will take place in populated areas within friendly countries or at least countries where the United States would like to end support for ISIL, U.S. artillery would require highly precise targeting and munitions to provide fire support without causing excessive collateral damage. Remote, continuous observation of targets and the use of munitions with reduced areas of effect could help achieve that goal. In this sense, the use of artillery against ISIL could resemble its recent use in Iraq and Afghanistan, where U.S. forces also strove to minimize collateral damage.

Summary—Challenges for U.S. Army Artillery

The foregoing discussion has shown that U.S. ground fires forces would face the following fundamental challenges in a potential future conflict with ISIL:

- U.S. fires would need to be integrated in support of allied ground armies with which we are not now training regularly and which probably would not be prepared to utilize U.S. fires capabilities.
- U.S. artillery would require highly precise targeting and munitions to provide fire support in urban areas without causing excessive collateral damage.
- Sufficient Army fires liaison teams would be required to coordinate fire support to allied armies down to battalion level.
- Procedural controls, which would slow the pace of coalition operations, could be needed to coordinate the provision of fire support to coalition partners.
- Army artillery might or might not have access to fire bases in the counteroffensive against ISIL; U.S. fires might have to be entirely provided by mobile forces.

China/Pacific

The Asia-Pacific region is becoming increasingly important to the United States because of its role in global commerce and the presence of important U.S. partners and allies. China has been rapidly and comprehensively modernizing its military forces in recent years. This, combined with the lack of transparency and openness from China's leaders regarding both its military capabilities and intentions, creates risk that tensions over long-standing sovereignty disputes or claims to natural resources will spur disruptive competition or erupt into conflict.

China claims sovereignty over several sets of islands, reefs, and shoals in the South China Sea and East China Sea whose ownership is also asserted by other nations. These include the Spratly, Paracel, and Senkaku Islands and the Scarborough Reef, Luconia Shoals, and Reed Bank. China has tried to various degrees to intimidate or interfere with the activities of Japan, Taiwan, the Philippines, Vietnam, and Malaysia regarding these territories. China also maintains that Taiwan is part of China, and responding to a potential contingency involving Taiwan remains the primary mission of the Chinese armed forces (DoD, 2015b, p. 46). Though perhaps not likely, escalated disputes over these territories or a Taiwan crisis could give rise to a military conflict between China and one or more of its neighbors and the United States (see also Dobbins et al., 2011, pp. 2–4).

In the time frame 2025 and beyond, a conflict involving China and the United States, outside of a North Korean collapse, would involve mostly U.S. air and maritime forces. This is because of the geography of the South China Sea and East China Sea regions but also because the direct defense of territories close to China, such as Taiwan, will become increasingly difficult as Chinese military capabilities grow (Dobbins et al., 2011). This scenario, or portion of a scenario, depicts how future Army artillery capabilities could contribute in such a conflict, which would otherwise involve non-Army forces. Specifically, it shows how long-range Army missile fires could supplement fixed-wing aircraft and air- and sea-launched cruise missiles in attacking critical targets in China, such as command-and-control (C2) sites, airfields, missile sites, and ports. It also shows how an Army land-based ASM (LBASM) could be used against Chinese naval forces that approached territories where Army forces were located.

Theater Geography

This scenario is dominated by the geography of the western Pacific Ocean and the South China Sea and the distances between China, any disputed territories, and the locations—allied nations and Guam—where U.S. forces would be based. It is 150 km from China to Taiwan, 320 km to South Korea, 670 km to Okinawa, 730 km to the northern Philippines, 840 km to southern Japan, and 3,000 km to Guam. The western Pacific region is depicted in Figure 2.16 and the South China Sea in Figure 2.17.

The Conflict

China possesses large air, naval, and missile forces it could bring to bear in a conflict in the western Pacific or South China Sea. It possesses 2,100 combat aircraft, more than 300 warships, 1,200 short-range ballistic missiles, 100 medium-range ballistic missiles (MRBMs), plus cruise missiles (DoD, 2015b, pp. 8, 80; O'Connor, 2012).

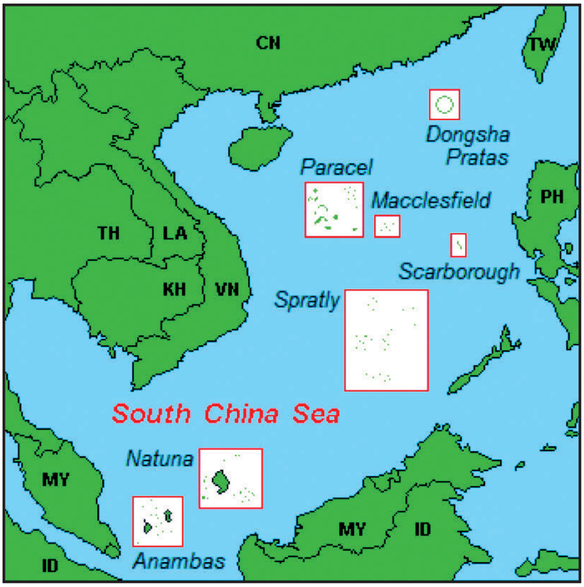
Figure 2.16
Western Pacific Ocean

RAND *RR2124-2.16*

The general nature of the conflict would likely depend on the subject of the dispute. In a conflict over Taiwan, combat could transition from lower to higher intensity over a period of time, as China escalated from coercion to invasion, or it could begin at high intensity with an invasion attempt from the outset. In conflicts over other disputed territories or economic zones, combat would be more likely to start at low intensity or with isolated incidents and then potentially escalate as each side sought to end the conflict on its terms.

U.S. and allied or partner forces that could be involved in a conflict vary widely. The United States has a carrier strike group based in Japan. It has two fighter wings based in South Korea and two in Japan. It could bring additional naval and air forces to bear if there

Figure 2.17
South China Sea and Disputed Territories



SOURCE: Behr, 2007.
RAND *RR2124-2.17*

was some period of tension or warning before a conflict. Army forces that would participate in the conflict would also have to be transported into the area. Taiwan possesses about 25 mostly smaller warships and about 290 combat aircraft. Japan possesses 124 warships and will possess about 420 combat aircraft in the near future (Pike, 2016; "World Air Forces 2016," 2015). The Philippines possess about 80 mostly small warships and 10 fighter aircraft. Vietnam possesses about 70 mostly smaller warships and 85 combat aircraft. Malaysia possesses about 25 mostly small warships and 85 combat aircraft. Allied or partner forces actually involved in the conflict would depend on which nation was the target of Chinese aggression, where the conflict started, and how it would or would not escalate.

In a conflict over Taiwan, the United States would aim to prevent Chinese coercion or conquest and limit the damage inflicted on Taiwan. It would attempt to prevent China from gaining air and sea dominance and limit the impact of Chinese missile attacks. U.S. military operations could include strikes on Chinese mainland targets associated with operations against Taiwan. As noted, in the coming decades, it will become increasingly difficult for the United States to prevent a Chinese invasion of Taiwan if China is strongly committed to carrying it out.

In a conflict over other disputed territories or economic zones, if the United States became directly involved, its goals could range from enforcing freedom of navigation against Chinese efforts to control the South China Sea, to helping the Philippines, Vietnam, or Malaysia defend themselves. In a conflict involving Japan, the United States would help defend Japan and aim to regain control of the surrounding airspace and waters. It would also aim to maintain the position that it is the preferred security partner for the nations of Asia. Such a conflict could involve strikes against the Chinese mainland, if necessary, to counter Chinese military operations. Because China's capabilities to project power at a distance are currently limited, particularly because it lacks an aircraft carrier fleet and air refueling capabilities, the defense of the nations of East Asia should be feasible over the next 20 years.

Implications for Future Fires Capabilities

Because conflicts with China in the western Pacific region likely would not involve U.S. conventional ground forces, the Army role, with its current capabilities, would likely be limited. However, two potential new Army systems could allow the Army to contribute more significantly. First, if the Army developed a long-range surface-to-surface missile system, with a range of 1,000 km or more, Army forces could potentially strike targets on the Chinese mainland from territories in the region where U.S. forces could be based and indeed from countries that might be the object of Chinese attacks. Second, if the Army developed an LBASM, Army forces could defend those countries against approaching Chinese warships or interdict Chinese commerce.

The reach of a notional surface-to-surface missile system with a range of 1,200 km is depicted in Figure 2.18.

Such a system could be an MRBM, conventional cruise missile, or hypersonic missile. It would allow Army artillery forces to strike

Figure 2.18
Reach of 1,200-km Missile System in Western Pacific

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targets in China that could otherwise only be attacked using air or maritime platforms. As such, it would add flexibility to the joint force (although it might also be seen as redundant given other U.S. long-range strike capabilities). If the new missile was highly survivable, it could increase the probability that U.S. strikes would penetrate Chinese air and missile defenses. If the missile was relatively fast, either a ballistic or hypersonic missile, it could enable attacks against fleeting targets that would be difficult to hit with slower-responding means such as fixed-wing aircraft or conventional cruise missiles.

However, there are several requirements or conditions that would have to be met to enable the missile to be utilized and to be effective. It would require a prompt, long-range targeting capability, survivable over China. Large numbers of missiles—hundreds or even thousands—would have to be procured for it to have significant military effects in a large conflict. Because it would be significantly different than existing Army systems, the new system would require the development of a new Army organization to support it. Such a new organization—and the system itself—would potentially not be available by 2025. A missile with that range could be seen as destabilizing in Europe because of its potential as a nuclear threat. On the other hand, Russia and China possess conventional ballistic missiles now. Finally, basing and employing the system would require agreement from regional partners. In that sense, employing it would be similar to flying U.S. aircraft from allied or partner-nation bases.

The second potential new system, an Army LBASM, would allow Army forces to fire on Chinese shipping that approached territories where Army forces were deployed. It would allow Army artillery to defend against attacks by Chinese warships or interdict Chinese commerce. It would also allow Army artillery to participate in security cooperation initiatives designed to help U.S. allies and partners improve their maritime anti-access capabilities. A capability to cut off Chinese seaborne access beyond the "first island chain" could serve as a deterrent and limit China's ability to attack its regional neighbors and wage a prolonged war (Kelly et al., 2013).

One of the current Army initiatives is to develop cross-domain fires capabilities. An LBASM would constitute one such capability.[12] The system could have a range of 150 to 200 km, or longer, and could be developed to be fired from existing launch platforms—Multiple Launch Rocket System (MLRS) and HIMARS. It could be air-transportable and tactically mobile. As shown in Figure 2.19, depending on the nations involved in a conflict with China, the systems could theoretically be deployed to interdict maritime traffic from Indonesia, in the south, up through the Philippines, Taiwan, Japan, and South Korea, in the north.

As with a surface-to-surface missile, there are several requirements or conditions that would have to be met to enable an LBASM to be uti-

[12] See Turner et al. (2016) and LTG H. R. McMaster, quoted in Freedberg (2016).

Figure 2.19
Potential Coverage of LBASM for Interdicting Chinese Maritime Traffic

SOURCE: Google Earth, with overlays based on geospatial analysis reported in Kelly et al. (2013, p. 13).
NOTE: Regions in red indicate potential LBASM coverage.
RAND *RR2124-2.19*

lized effectively. It would need a supporting targeting capability, potentially from other services or partner nations, to engage ships. If it were to be used to implement a blockade, it would have to be paired with forces that could challenge and board ships. Large numbers of missiles would have to be procured for it to have significant military effects in a large conflict. Because it would be significantly different from existing Army systems, it would require the development of a new Army organization to support it. Such an organization and the system might not be available by 2025. Basing and employing the system would require agreement from regional partners. Finally, while not a requirement or condition for use, it may be observed that the joint force currently possesses robust capabilities, both sea- and air-based, for targeting and engaging enemy ships. In light of those capabilities, an Army LBASM could be seen as redundant or not addressing the Army's or the joint force's most urgent capability needs.

Summary—Challenges for U.S. Army Artillery

The foregoing discussion has shown that Army artillery would face the following fundamental challenges in supporting the joint force in a potential future conflict with China in the South China Sea or East China Sea:

- With U.S. ground forces not in contact with Chinese, the long distances from East Asia bases to China would require a new missile system to enable Army artillery to strike land targets; a new system would also be required to engage enemy ships approaching locations where Army forces were positioned.

  With respect to a new surface-to-surface missile:

- A 1,200 km MRBM (or ground-launched cruise missile [GLCM]) would have to be developed to cover much of eastern China from South Korea, Japan/Okinawa, or the Philippines.
- Employing such a missile system would require a prompt, long-range targeting capability, survivable over China.
- A new system and a new Army organization to support it would potentially not be available by 2025; large numbers of missiles would be required for it to have significant military effects.
- A missile with range greater than 500 km could be seen as destabilizing in Europe because of its potential nuclear threat.
- Basing and employing the system would require agreement from regional allies.

With respect to a new LBASM:

- The system would have to be developed; with a range of 150 to 200 km, it could interdict Chinese maritime traffic, from Indonesia up through South Korea.
- Employing such a system would require the use of other services' or nations' capabilities to target Chinese ships.
- Employing an LBASM to implement a blockade would require additional forces that could challenge and board ships.
- A new system and a new Army organization to support it would potentially not be available by 2025; large numbers of missiles would be required for it to have significant military effects.
- Basing and employing the system would require agreement from regional allies.
- Because of the joint force's existing capabilities for targeting and engaging enemy ships, an Army LBASM might be seen as redundant or a low priority.

CHAPTER THREE

Threat Capabilities Relating to Army Fires

This chapter is intended to augment the discussion in previous chapter by providing more-detailed considerations relating to threat capabilities for future Army fires. This chapter is not a comprehensive threat assessment, but will provide further detail on a few example threat capabilities to inform answers to the following questions, which will be addressed in the assessment chapter.

- *Target Sets*: What are the main target sets that Army fires will be required to service? How should priorities among them be determined?
- *Counters*: What are the major countermeasures intended to limit the effectiveness of Army indirect fires, and how should they affect modernization and training priorities?
- *Threats*: What are the major threats to Army field artillery units themselves, and how should they affect modernization and training priorities?

Target Sets

Fires can be employed in many different ways against a wide variety of targets in order to support the aims of an operation. This section outlines the major classes of target sets to be considered in the assessment.

Maneuver Forces

One traditional target of indirect fires has always been an enemy's maneuver force. Artillery is of particular use in disrupting an adversary's scheme of maneuver when attempting to conduct large-scale operations, but its flexibility also provides the ability to respond with fires when an adversary shows up in an unanticipated place. Some adversaries employing armored fighting vehicles may call for the employment of specialized area munitions with anti-armor capabilities, such as DPICM or sensor-fuzed weapons.

Field artillery fires can also be employed in a counter-mobility role against enemy maneuver forces. Engaging enemy units in choke points (a very important issue in Korea due to the numerous narrow valleys) can have a significant impact on the ability of the opponent to maneuver.

Enemy Indirect Fires Units

Countering enemy indirect fires is a key mission of Army indirect fires, as in some situations it will be the most responsive capability available. Enemy units may fire mortars, cannons, rockets, or missiles. In the counterfire battle, range becomes more important to attack enemy systems further behind the front lines; although most enemy tactical artillery systems are likely to be employed relatively close to the front, certain high-priority systems, such as missiles, may be much deeper. Self-propelled howitzers with enclosed turrets will tend to operate in a dispersed fashion and shoot-and-scoot; area anti-armor capabilities may be necessary for effective counterbattery fires. These will be somewhat more survivable than rocket artillery systems, which are less well-armored; either will be considerably more survivable than towed guns employed by most adversaries, except when those guns are able to be concealed and occupy hardened positions.

Air Defenses

For the purposes of this research, enemy air defenses are divided into two subcategories: IADS and SHORAD.

- Countering the IADS of an adversary is a mission for the whole joint force but one to which U.S. ground-based fires may make a critical contribution. An adversary with a well-developed, modern, mobile IADS will not be easy to target with rotary-wing or all but fifth-generation fixed-wing aircraft. A need may exist for a fast, survivable ground-fired munition with some ability to acquire adversary emitters or otherwise help suppress the most capable of an enemy's air defense systems. One important example system is the S-400, which is built and fielded by Russia and is being sold to China. In the time frame of this study, the S-400 (SA-21) may well proliferate to a variety of other countries to replace or augment the more widely available S-300 series (SA-10 and SA-20).
- The threat of SHORAD to joint fixed-wing aircraft varies based on the capability of the system; in some cases, the joint force may find it necessary to devote resources to other priorities and will leave some shorter-ranged systems to the Army to deal with if it wants to employ Army rotary wing aircraft or unmanned aerial systems. These may also be time-sensitive targets; some short-ranged systems will employ only optical or electro-optical (EO) aiming and will therefore not emit.

In both cases, special guidance for indirect fire munitions may provide additional capability against emitting targets. These will not tend to be particularly well armored, but may be dispersed and concealed to avoid attacks from the air.

Logistics

Logistical convoys are soft targets and may provide an option for degrading the ability of an adversary to continue sustained operations if fuel and munitions cannot be provided to combat forces. This is particularly the case for an adversary's rocket artillery; since the ammunition for these systems consists of very large, bulky munitions that require a large number of trucks to transport to the launchers. If the adversary's logistics system can be identified, targeted, and engaged, there could be considerable tactical and operational benefit to the U.S. and coalition force.

Command and Control

Attacks on an adversary's command posts and communications nodes are commonly part of a campaign plan given the dramatic effect this can have on the enemy's ability to respond to U.S. moves on the battlefield. Army indirect fires will play some role in this, particularly at the tactical level or against mobile, time-sensitive targets (which may be those most likely to survive to get within range of U.S. ground forces in many scenarios).

Intelligence-Surveillance-Reconnaissance Capabilities

This is a relatively broad category as it includes both a variety of ground-based sensors and ground stations for aerial and space-based sensors. One of the primary targets will be ground-based radars, including those used for battlefield surveillance or for counterbattery. Given the challenge of eliminating deployed artillery units, reducing their ability to receive accurate, timely targeting information is a key way to degrade their effectiveness.

Electronic Warfare

A variety of adversaries will employ EW capabilities to attempt to degrade U.S. communications and sensors. Enemies conducting electronic attack are by definition emitting and can be detected; however, localizing them may be challenging. In some cases, it may be challenging to identify the particular antenna even with an observer within line of sight of the emitter; in others, is emitting by definition but may be difficult to localize. This can be further complicated by the challenge of GPS jamming (countering the observer's ability to generate an accurate location as well as the ability of some precision-guided shells to target them).

A potentially major challenge for U.S. forces should they have to fight the Chinese or Russian militaries will be the overall EW environment. Both the Russians and Chinese place considerable emphasis on EW and intend to be very aggressive in this area. With U.S. forces spread over large areas due to the limited force structure, secure, reliable communications for mission command and application of fires will be critical. However, achieving those goals will be difficult when operating against opponents who are prepared to make aggressive use of offensive EW.

The Russian ground forces, for example, have separate EW brigades and battalions available at the operational level, but also have fielded EW companies in maneuver brigades. The EW company in a motor rifle brigade has detection, direction finding, and jamming capabilities that can affect satellite communications, GPS, and high-frequency and ultra high-frequency (UHF) communication. The Russians have also fielded a jammer that has some capability to affect variable time artillery fuses.

As suggested by the image above, EW systems hidden among other antennae in populated areas, or even in wooded areas or complex terrain, may be challenging to find, even if they are relatively soft targets.

Aviation

Depending on the opponent, there may be a considerable enemy aviation force to contend with. While it is not the role of field artillery to engage enemy aircraft in flight, the field artillery may be able to engage hostile rotary-wing aircraft when they are on the ground refueling and rearming. The range of some field artillery munitions, such as the GMLRS, which is capable of engaging targets over 80 km distant, could provide the means to engage enemy helicopters when they are on the ground between missions. Rotary-wing aircraft are not designed to resist artillery fragments, and the light construction of most rotary-wing aircraft means that even a near miss from an artillery round could disable or destroy an aircraft on the ground. The equipment and stored fuel and ammunition associated with a forward arming and refueling point (FARP) are also vulnerable to artillery attacks.

WMD or Other Strategic Targets

This category exists as a catchall: There are a variety of targets that could be engaged by ground-based fires based on their importance to the joint commander. In the North Korean case, ground-based fires could support the isolation of a WMD facility until friendly forces can arrive and secure it. They could also attack enemy WMD launch capabilities before they are utilized. The existence of such targets varies by scenario.

Counters

This section is intended to outline some of the countermeasures that potential adversaries may apply to limit the effectiveness of ground-based fires. Broadly, they consist of deception efforts, including camouflage, concealment, and decoys; positional measures, including mobility and dispersion; EW; and hardening efforts, including armor, complex terrain providing cover, and prepared fighting positions.

Deception

Traditional means of using camouflage, concealment, and deception to reduce the risk of detection are being augmented as technologies improve. A number of foreign countries have fielded signature management solutions for vehicles—these include *Nakidka* in Russia and the Barracuda camouflage system from Saab (Saab, undated). These camouflage technologies are also available for fixed ground positions and can reduce the effectiveness of thermal or radar sensors attempting to generate targets.

In addition to improving camouflage, adversaries are developing higher-fidelity decoys. These may eventually require fairly sophisticated multispectral approaches to discern from real units. The risk of decoys to ground-based fires is twofold; not only does firing on them result in wasted munitions, but it can also reveal the location of the fires units and provoke counterbattery fire.

Positional

This is a simple and relatively straightforward tactics, techniques, and procedures (TTP)–based solution to reduce vulnerability to fires that is still somewhat challenging to fully overcome. An adversary with a truly mobile force can be difficult to target if using terrain effectively to screen movements. A dispersed adversary also limits the vulnerability of its force to massed fires, if operating in an area that permits dispersion (and not in such proximity to an enemy ground force that it risks defeat in detail). Both of these are challenges calling for either terminally guided munitions (which are expensive, especially when many are called for) or area fires (which may be difficult to gain approval for in some cases, depending on the weapon system and the target area).

Hardening

The opposite of movement: Some adversaries, notably the North Koreans, will rely on hardened positions requiring special penetrating ammunition, precise fires, or both to achieve effects.

Electronic Warfare

EW affects indirect fire in several ways. First, it can reduce the effectiveness or likelihood that the units it is protecting are detected or effectively targeted. Second, it can attack communications in ways that hinder responsive fires: by degrading control of UASs, or by disrupting communication between observer and fire direction center. Finally, when guided rounds are used, some may be degraded in effectiveness if they rely on signals that are denied or degraded by an EW system.

Threats

The primary threat class of concern here is counterbattery fires. Other threats exist: improvised explosive devices and mines, and the risk of encountering enemy maneuver units, but those are challenges that are common to the broader force, while the threat of counterfire by an adversary with capable counterbattery radars tied in to effective fire direction and ground-based fires is unique to artillery. The demands placed on artillery are for some mix of increased survivability (frequently in the form of armor, at least against artillery fragments), increased mobility (meaning, at a minimum, self-propelled guns where an adversary can pose this threat), and increased range, to enable some degree of standoff (distance from the enemy's counterbattery radar increases the amount of time to displace and potentially decreases the accuracy of an enemy's targeting solution; distance from an enemy's artillery increases the time of flight and decreases the accuracy of unguided rounds).

Across the five scenarios discussed in this report, the adversary most capable of employing counterbattery fires is the Russian Federation. The Russians have traditionally prized artillery fire support and have retained a heavy emphasis on ground-based fires to this day (in part reflecting a relative lack of joint integration between the Russian Ground Forces and Aerospace Forces). Their most capable system for counterbattery fire is the 9A52 *Smerch* 300mm rocket system.

The *Smerch* (Russian for *cyclone*) is a 300mm rocket system that fires course-corrected rockets with a variety of payloads. The legacy Cold War–era rockets that this system can fire have ranges between 20 and 70 km; modernized rockets carry the same 243-kg payload from 25 to 90 km, and one reduced-payload rocket has been developed that can reach 120 km. Each launcher carries 12 rockets, and each rocket can carry a variety of submunitions, high-explosive (HE), scatterable mines, or thermobaric warheads (U.S. Army Training and Doctrine Command, 2015, pp. 7–49).

In addition to Army-level systems such as the BM-30, Russian maneuver brigades include a battalion of BM-21 122mm MRLs that currently can strike targets 40 km away.[1] While shorter-ranged than the *Smerch*, the 122mm systems are much more numerous. Together, the 300mm, 220mm (35-km range), and 122mm rockets available to the Russians (who also market these weapons to other countries) represent a significant threat to U.S. field artillery units. In fact, fires from enemy MRLs probably represent the greatest danger to the Army's field artillery when fighting a conventional opponent.

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1 Реактивная система залпового огня «Град» ("Reactive System for Salvo Fire '*Grad*'") website, 2017.

CHAPTER FOUR

U.S. Army Current and Potential Indirect Fire Capabilities

This chapter outlines the current fire support capabilities available within the U.S. Army, as well as potential areas for future capability development, both those that have been considered as part of the future program of record and others that have not been considered but are technically feasible in the mid- and far-term (2020–2035) time frame. It is organized into three sections. First, it covers current capability and those systems that are in the midst of fielding in the near-term future. Second, it includes a discussion of the current program of record (in the program-of-record period) and elements of the Army's declared modernization strategy out into the mid term. Finally, it outlines potential new capabilities that could be developed for the future artillery force.

Current Capability

The Army uses a variety of weapons to provide indirect fires to its maneuver forces. These weapons have different capabilities and limitations, which inform how they are used. The Army uses mortars, howitzers, rockets, and missiles at various echelons, from the company level in some cases up to the field artillery brigade. Broadly speaking, the Army uses mortar systems at the battalion level and below; it uses howitzer systems at the brigade level and in some Army National Guard field artillery brigades; and it uses rocket artillery systems (which may also fire a tactical ballistic missile system) at the division and corps level in separate battalions and brigades.

Mortar Systems

Mortars are used in the U.S. Army for fire support at the battalion level and below. Compared with the other indirect fires systems in use, mortars are simple and inexpensive, have a variety of munitions available, and are capable of very high rates of fire for short periods; their primary drawback is their relatively short range. In addition to suppressive and destructive fires, mortars are very commonly used for illumination and obscuration.

Although they may be mounted on or towed by different vehicles, there are only three basic kinds of mortars in service. Table 4.1 outlines their basic characteristics.

The 120mm mortar is also noteworthy for being able to accept the XM395 Accelerated Precision Mortar Initiative (APMI) kit, which provides GPS guidance to 120mm rounds.

All three types of brigade combat teams (BCTs) are equipped with mortars for fire support at the battalion level and below. The IBCT is

Table 4.1
Mortars in Use by the U.S. Army

Type	Range (m)	Rate of Fire	HE Cartridge Weight	Ammunition Types
M224 60mm mortar	3,489	30/min for 2 min; 20/min sustained	3.8 lbs (1.7 kg)	HE, white phosphorus smoke, visible, and IR illumination
M252 81mm mortar	5,935	30/min for 2 min; 15/min sustained	9.2 lbs (4.2 kg)	HE, red phosphorus smoke, visible, and IR illumination
M120 towed, M121 vehicle-mounted 120mm mortar	7,240	16 for 1 min; 4/min sustained	30 lbs (13.6 kg)	HE, white phosphorus smoke, visible, and IR illumination

NOTE: IR = infrared.

equipped with the following mortars (U.S. Army, Maneuver Center of Excellence, 2015):

- Each IBCT infantry company has a mortar section with two M224 60mm mortars.
- Each IBCT infantry battalion has a mortar platoon with four M252 81mm mortars and four M120 120mm mortars.
- Each motorized troop in the IBCT's cavalry squadron has two 120mm mortars, and the dismounted troop has two 60mm mortars.

All of the IBCT's mortars are towed or man-portable. The M120 120mm mortars provide substantial firepower for the infantry battalion; the 81mm mortars are there for circumstances when it is not feasible to bring the heavier M120s.

SBCTs are equipped with a large number of mortars (U.S. Army, Maneuver Center of Excellence, 2015):

- Each Stryker infantry company and cavalry troop has two M1129 Stryker Mortar Carrier vehicles, equipped with the M121 120mm mortar system; these vehicles also carry 60mm mortars for dismounted operations.
- Each Stryker infantry battalion has a mortar platoon with four M1129s with 120mm mortars, and also 81mm mortars for dismounted operations.

In total, the SBCT has 36 120m mortars, in addition to those available for dismounted missions. As with the IBCT's mortars, there are only enough crews to operate the weapons in the Stryker mortar carrier vehicles or the dismounted light and medium mortars.

The ABCT has the following mortar systems (U.S. Army, Maneuver Center of Excellence, 2015):

- Each combined arms battalion has four M1064 mortar carriers with M121 120mm mortars.
- Each cavalry troop has two M1064s.

The ABCT is less reliant on mortars to generate firepower given the high direct firepower of its organic tanks and infantry fighting vehicles, but its mortar systems do provide important obscuration and suppressive fires to support maneuver.

Cannon Systems

Howitzer systems, whether towed or self-propelled, are the primary brigade-level fire support units in the Army. Compared with mortars, howitzers are much larger and heavier and fire larger projectiles at greater distances, but at lower rates of fire (Table 4.2).

The 155mm cannons in the Army's inventory are also capable of firing the M982 "Excalibur" GPS-guided projectile, which has a maximum range of almost 40 km when fired from a 39-caliber gun (both the towed and self-propelled 155mm howitzers in service in the Army have 39-caliber barrels) (U.S. Army, Acquisition Support Center, undated-b). There is also an older precision round, the M712 "Copperhead," which is laser-guided, though it has more limited range (16 km). Of additional note, the Army has also funded the M1156 Precision Guidance Kit (PGK) fuze for full-rate production as of 2016; this will provide a much more cost-effective precision capability as it leverages existing ammunition, although these will not have the extended range of Excalibur ("Orbital ATK Signs $69 Million Contract to Produce Artillery Precision Guidance Kits Through 2019," 2016).

Table 4.2
Howitzers in Use by the U.S. Army

Type	Range	Rate of Fire	HE Projectile Weight	Ammunition Types
M119A3 105mm	14.5 km 19 km (RAP)	6/min for 2 min 3/min sustained	39.92 lbs (18.11 kg)	HE; DPICM; white phosphorus smoke; rocket-assisted
M777A2, M109A6/A7 155mm	22.6 km 30 km (RAP)	4/min for 3 min 1/min sustained	103 lbs (46.7 kg)	HE; DPICM; white phosphorus smoke; rocket-assisted; FASCAM

Each BCT has an organic field artillery battalion equipped with 18 howitzers, organized in three batteries of six guns each:

- The IBCT's field artillery battalion has two batteries of M119 105mm howitzers and one battery of M777 155mm howitzers.
- The SBCT's field artillery battalion has three batteries of M777 155mm howitzers.
- The ABCT's field artillery battalion has three batteries of M109A6 Paladin self-propelled howitzers.

Only the IBCT still fields 105mm howitzers; although they are less capable, they are much lighter than 155s and may be towed by a High-Mobility Multipurpose Wheeled Vehicle (HMMWV). The IBCT's single battery of 155mm howitzers gives it an extended-range precision capability, albeit in limited numbers.

The Army's sole remaining self-propelled howitzer is the M109A6 Paladin (Figure 4.1). The M109 series of howitzers has been in service

Figure 4.1
M109A7 Self-Propelled Howitzer

SOURCE: U.S. Army, Program Executive Office Ground Combat Systems, no date.
RAND *RR2124-4.1*

for over half a century, and has been modernized repeatedly. The latest version, currently in low-rate initial production, is the M109A7.

When fielded, the M109A7 will be almost a completely different vehicle than the original M109. It, and its companion ammunition supply vehicle, the M992A3, have been rebuilt around a new hull that has substantial commonality with the Bradley fighting vehicle. Although some elements of the weapon system are being improved in the new vehicle, the major improvements will be on the vehicle's reliability and automotive performance.

Rocket/Missile Systems

The Army has two rocket launcher systems: the tracked M270A1 MLRS and the wheeled M142 HIMARS. Both systems fire the same family of 227mm rockets, as well as a tactical ballistic missile, the ATACMS. Both are fielded in field artillery brigades and in some cases at the division level. Figure 4.2 shows HIMARS firing ATACMS.

Compared with cannons and mortars, the Army's rockets fire much farther and carry much heavier lethal payloads. Although originally designed with a very heavy DPICM payload, the main rocket currently employed is the GPS-guided M31 GMLRS rocket, which has a unitary HE warhead. The rockets are loaded onto the launchers in pods of six; two pods may be loaded onto the MLRS launcher, while HIMARS can carry one.

In addition to rockets, both launchers can fire the MGM-140 ATACMS missile. Like the MLRS rockets, ATACMS was originally developed with a submunition payload, but the primary version in current use has a unitary HE warhead (ATACMS Block 1A Unitary). ATACMS is a 610mm missile that has a maximum range of about 300 km.

Both GMLRS and ATACMS were used extensively in Iraq; GMLRS, being highly accurate and with a 200-lb unitary warhead that limits collateral damage relative to air-delivered ordinance, has earned a reputation for accuracy and has been used in close proximity to troops. This is a somewhat atypical use of rockets, which historically have often been used to saturate large areas with large amounts of explosives or large numbers of submunitions.

Figure 4.2
HIMARS Firing ATACMS

SOURCE: Promotional image from Lockheed Martin.
RAND *RR2124-4.2*

The Current Program of Record

The Army Equipment Modernization Strategy (AEMS) lays out a set of near-term, mid-term, and long-term objectives for the indirect fires portfolio. The focus of this study is on the mid term and beyond, but this assessment must be informed by those programs that are already being executed (U.S. Army, G-8, Future Force Division, 2015):

- In the **near term**, over the next five years, the Army intends to begin full-rate production of the M109A7 self-propelled howitzer and its companion ammunition supply vehicle. The Army is also developing a replacement for the ATACMS missile called the Precision Strike Missile (PrSM) missile.[1] A considerable area of emphasis has also been the improvement of Army target location capabilities, to facilitate the employment of the Army's growing suite of precision munitions.
- In the **mid term**, over the course of the 2020s, the Army's priority will shift to the development of capabilities with enhanced range, responsiveness, and accuracy; this explicitly includes enhanced-range cannon systems. The AEMS also states that a new, common rocket launcher module will be developed for fielding in this time frame, as the MLRS and HIMARS launchers approach their end of useful life.
- In the **long term**, the focus is on enhancements to towed artillery systems, as well as target location capabilities and synergy with Army air and missile defense capabilities. The fires portfolio will also need to continually consider new vehicle capabilities to pace developments with the rest of the force, which will likely include the development of a "new, lighter, self-propelled howitzer."

Conventional HE rounds can be effective against armored targets, but the numbers of rounds required to achieve effects can be substantial.[2] Improvements to weapon accuracy will help. One of the

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1 U.S. Army, "Precision Strike Missile," webpage, undated.

2 See, for example, Durham (2002, pp. 8–11).

areas where this is particularly important is in counterbattery fires; the original M26 rocket for the MLRS launcher was designed to facilitate the saturation of large areas with submunitions to destroy enemy artillery that may not have been perfectly located or was in the process of moving from its firing position.

In part with this mission in mind, the Army is pursuing the development and fielding of the GMLRS Alternative Warhead, which provides some of the effects of DPICM against area targets. It features a warhead designed to propel 160,000 tungsten fragments over an area for maximum effect against light armor, light vehicles, dismounted troops, or other targets lacking considerable armor protection. As suggested in Figure 4.3, it will likely be highly effective in some roles where the target set is lightly protected.

Figure 4.3
GMLRS Alternative Warhead Effects on BM-21 Test Target

SOURCE: Screen capture from COL Gary Stephens, Precision Fires Rockets and Missiles, Program Executive Office for Missiles and Space, U.S. Army, presentation at the National Defense Industry Association Precision Strike Annual Review, March 18, 2015.
RAND *RR2124-4.3*

Foreign Artillery Systems for Possible U.S. Army Use

There are a number of excellent foreign field artillery systems that the U.S. Army might consider. These include cannons, rocket launchers, missiles, and ISR or targeting systems. For example, the German PzH 2000 155mm howitzer is the most capable self-propelled artillery cannon system in the world today. With a range of roughly 50 km with rocket-assisted munitions, considerable armored protection, and a very high rate of fire (eight rounds per minute), the PzH 2000 might be a viable candidate for U.S. use should some of the other programs to improve the capabilities of the M109-series weapons prove unsuccessful (Gordon et al., 2015, pp. 19–34).

A number of countries are also developing long-range fiber-optic guided weapons that might have applicability for U.S. Army field artillery. Examples include the Israeli Spike system and the French Polyphem long-range fiber optic weapon ("Polyphem Fiber-Optic Guided Missile System," 2017). While a foreign howitzer system such as PzH 2000 would be relatively easy to introduce into current U.S. Army structures, a long-range fiber optic missile would require new operational concepts, and perhaps new force structure, to accommodate the system. That said, there are a number of promising foreign systems that the Army could consider for introduction into its field artillery units.

CHAPTER FIVE

Joint Fires

Joint fires refers to the coordinated employment of fires delivered from more than one military service. The intent of this chapter is to review the current and mid-term future capabilities that other services will be contributing to the joint fight, to enable the Army to better account for them in its own fires modernization planning.

To provide a framework for the consideration of joint fires capabilities, we begin by classifying the tasks they are expected to execute and targets they are expected to engage. Tasks are categorized as close support, interdiction, counterfire, and a subset of counterair—SEAD. Close support entails the employment of fires against threats in sufficiently close proximity of friendly forces that detailed coordination of fire and maneuver units is required (e.g., CAS). Interdiction entails the employment of fires against threats at ranges great enough that detailed coordination of fire and maneuver units is unnecessary; ideally before the threat can engage friendly forces (e.g., shaping fires beyond the coordinated fire line). Both counterfire and SEAD entail protecting friendly forces to enable maneuver. The counterfire task has particularly demanding time lines, while the SEAD task typically requires very specialized munitions (and can have demanding time lines in some cases). Joint fires have responsibilities for other tasks as well, but those fall outside the scope of this work (Joint Publication 3-09, 2014).[1]

[1] We do not consider countering air and missile threats, strategic attack, or information operations here, as they fall outside the scope of this report. Similarly, we do not consider chemical, biological, radiological, nuclear, and explosive targets in the subsequent discussion.

Targets may be characterized based on their level of mobility, size, protection, and priority level. A target may be fixed, stationary, or moving. It may be a point or area target. It might be soft, armored, underground, or hardened. Each constellation of target characteristics—and the operational conditions under which it must be engaged—creates its own challenges, rendering the matching of appropriate fire support assets with the appropriate target critical to achieving desired effects. This activity is called weaponeering.

Figure 5.1 illustrates the types, range, volume, and modernization plans for munitions employed by the joint force, excluding unguided, cluster and Army-only munitions. In Figure 5.1, dotted lines indicate future capability, dark lines indicate higher-volume assets, and thin lines indicate capabilities soon to be phased out. This figure excludes cluster and unguided munitions (e.g., bombs).

In the next section, we assess whether the fire support assets the joint force will be able to provide in the future are appropriate for our selected scenarios, or whether there will be significant gaps the Army may need to address or adapt to.

Joint Fires Capabilities

Here we break fires into air-to-surface and surface-to-surface capabilities.[2] Among air-to-surface fires capabilities, we consider are fixed-wing aircraft, attack helicopters, unmanned systems, standoff weapons, and precision weapons. Among surface-to-surface capabilities, we consider missiles, rockets, cannon, mortars, and naval surface fire support.[3] For each capability type, we consider concept of employment, assess its proficiency and sufficiency, and describe current inventory and investment plans.

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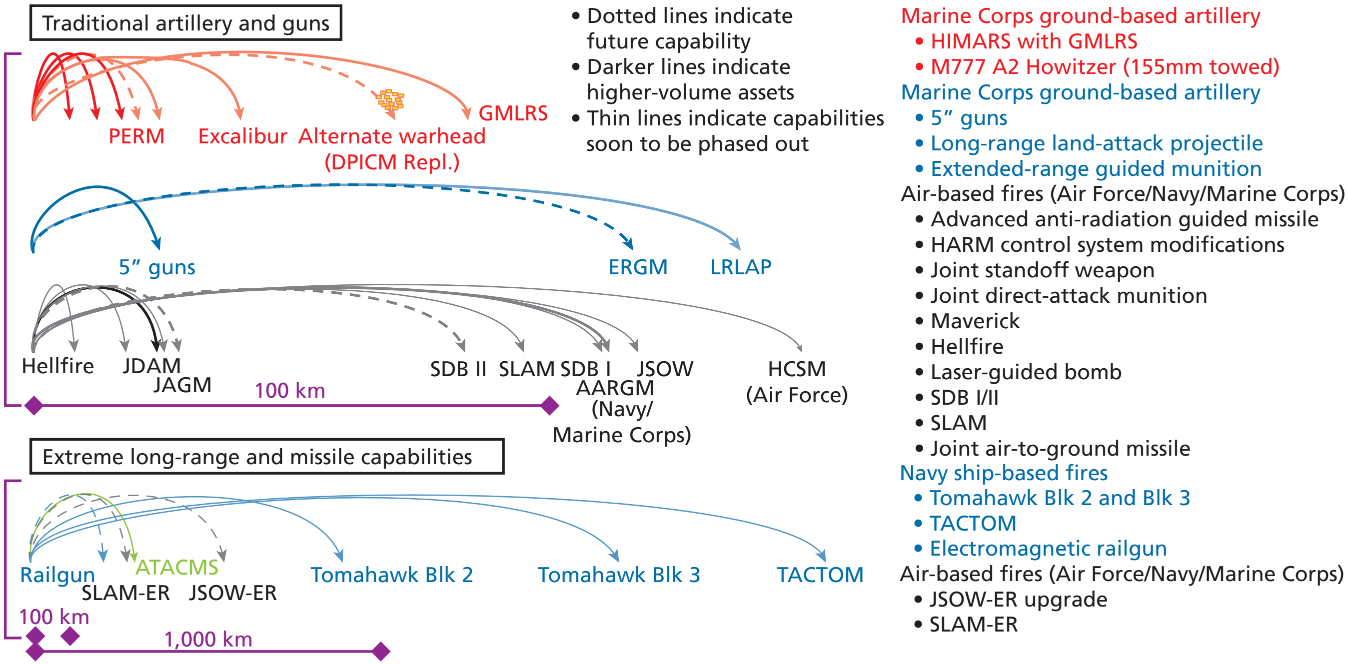
[2] This section draws heavily on International Institute for Strategic Studies (2016), Jane's Information Group (2016j, 2016k, 2016l), Joint Publication 3-09 (2014), Air Land Sea Application Center (2012), U.S. Marine Corps, MAGTS Staff Training Program (2012), Congressional Budget Office (2016), U.S. Air Force (undated), U.S. Navy (undated), U.S. Marine Corps Concepts and Programs (2016), Office of the Under Secretary of Defense (Comptroller) (2016), and the services' FY17 budget justification books.

[3] We exclude from consideration cyber, electronic attack, and nonlethal fires as out of scope.

Figure 5.1
Joint Fires Munitions, Range, Volume, and Modernization



NOTES: PERM = Precision Extended Range Munition; ERGM = Extended Range Guided Munition; LRLAP = Long-Range Land Attack Projectile; JDAM = Joint Direct Attack Munition; JAGM = Joint Air-to-Ground Missile; SDB = Small Diameter Bomb; SLAM = Standoff Land Attack Missile; JSOW = Joint Standoff Weapon; HCSM = HARM Control Section Modification; AARGM = Advanced Anti-Radiation Guided Missile; SLAM-ER = Standoff Land Attack Missile–Extended Range; TACTOM = Tactical Tomahawk.

RAND *RR2124-5.1*

Air-to-Surface Strike Capabilities

Fixed-Wing Aircraft

Platforms

Air Force fighter and attack aircraft carrying air-to-surface munitions include the F-35A Joint Strike Fighter, F-15E Strike Eagle, F-16C/D Fighting Falcon, A-10C Thunderbolt II, and AC-130. The A-10 in particular was designed specifically to engage in CAS, while the AC-130 has been adapted to focus solely on that mission. The F-22 Raptor and F-15C/D Eagle are primarily employed in an air superiority role against air threats, so will not be addressed further here.

Bombers are another important source of air-to-surface munitions, including the venerable B-52H and B-1B. Historically, the B-2 has been employed against strategic targets rather than in CAS or air interdiction (AI) roles, so it will not be considered here. Since the advent of precision munitions, bombers have shown themselves capable of providing CAS, though they lack the situational awareness of aircraft with sufficient survivability to loiter within visual range of the targeted area.

Navy and Marine Corps fixed-wing combat aircraft include the F/A-18A/B/C/D Hornet, F/A-18E/F Super Hornet, AV-8B Harrier II, and F-35B/C variants of the Lightning II. All of these aircraft perform both air-to-air and ground attack roles and can operate from aircraft carriers. The Super Hornet has a 41 percent longer mission range than the Hornet and a 25 percent greater weapon payload. The F-35B and AV-8B are vertical or short takeoff and landing–capable, so can operate from large-deck amphibious ships or austere airfields inadequate to the needs of most other fixed-wing combat aircraft. We consider the EA-18 here only briefly, since it is principally an EW platform.

Force Structure, Inventory, and Modernization

Table 5.1 shows the Air Force's fires-related force structure. The Air Force is planning to field 1,763 F-35As, replacing the F-16 and A-10. As of 2015, there are 75 F-35s in the Air Force inventory, with an additional 43 funded for procurement in the FY17 President's Budget request. The Air Force still has approximately 950 F-16C/Ds, and 294 A-10Cs. The Air Force still plans to implement a service life extension program (SLEP) for 300 F-16s, while the A-10's retirement has been deferred to 2022 due to congressional opposition (which may well continue beyond 2022). Currently, the Air Force has 219 F-15E Strike Eagles and expects to retain the F-15E beyond 2035, though it plans for the F-35 to be its primary strike aircraft. The Air Force holds 30 AC-130s, but has plans to procure 37 more.

The Air Force has 75 B-52Hs and 63 B-1Bs. The Air Force plans to replace both with the Long Range Strike Bomber (LRS-B, now designated the B-21) by the end of the 2040s. The Office of the Secretary of Defense's Strategic Capabilities Office is investing in development of an "arsenal plane" concept that would dramatically increase the munitions carried by long-range aircraft.

Currently, the Navy and Marine Corps have 617 F/A-18 Hornets, with the Navy retaining the aircraft through 2022, and the Marine Corps through 2030, to be replaced by F-35s. Many Hornets have flown more than 8,000 hours, though they were designed for only 6,000. The Navy is sending some Hornets through a SLEP and rebuilding others into Super Hornets as a bridge for managing F-35 procurement delays, while the Marine Corps is pulling Hornets from the Davis-Monthan Air Force Base "boneyard." The Navy has 514

Table 5.1
Air Force Fires-Related Force Structure

Unit Type	2017	2018	2019	2020	2021
A-10 Attack Aircraft Squadron	16	13	10	6	2
F-15 Fighter Aircraft Squadron	25	25	25	25	26
F-16 Fighter Aircraft Squadron	45	45	46	46	46
F-22 Fighter Aircraft Squadron	13	13	13	13	13
F-35 Fighter Aircraft Squadron	3	5	7	10	14
B-52 Bomber Aircraft Squadron	4	4	4	4	4
B-1B Bomber Aircraft Squadron	4	4	4	4	4
B-2 Bomber Aircraft Squadron	1	1	1	1	1

SOURCE: Congressional Budget Office, 2016.

F/A-18 Super Hornets, with plans to acquire a total of 563 (procuring ten in FY16), to be retained at least through 2035, and likely into the 2040s. The Marine Corps still has 132 AV-8Bs despite plans to retire them by 2012. Currently, the Marine Corps plans to replace the AV-8B with the F-35B by 2025.

The Navy plans to buy 260 F-35Cs, and the Marine Corps 67 F-35 Cs and 353 F-35Bs. Current software allows only an initial combat capability; the Block 3F software upgrade should be delivered in 2017, allowing for a more robust suite of weapons and EW assets to be employed.

The Navy maintains ten carrier air wings. There are nine Navy and 11 Marine Corps active Hornet squadrons, with two and one additional reserve squadrons, respectively. The Navy has 26 Super Hornet squadrons. The Marine Corps has six squadrons of AV-8Bs. The Navy does not yet have any operational F-35 squadrons; the Marine Corps has declared an initial operational capability for one squadron.

Armament

Internally, the F-35 can carry two 2,000-lb Guided Bomb Unit (GBU)-31 Joint Direct Attack Munitions (JDAMs), or eight 250-lb GBU-39 Small Diameter Bombs (SDBs). There are plans for it to accommodate the GBU-12 Paveway II, AGM-54 Joint Standoff Weapon, and GBU-32 JDAM as well. (*AGM* stands for "air-to-surface guided missile.") Externally, the F-35 can carry the AGM-158 Joint Air-to-Surface Standoff Missile (JASSM) or 24 SDBs, though this dramatically increases its radar cross-section. The F-35 will have only a basic CAS capability until it is able to employ these other munitions.

The F-15E can carry essentially any air-to-ground ordinance in the Air Force's inventory, including the 5,000-lb GBU-28, and up to 12 of the GBU-39 SDBs.

The F-16 can carry laser guided bombs, AGM-65 Maverick, AGM-158 JASSM, and AGM-88 High-Speed Anti-Radar Missile (HARM), and up to two GBU-31s, or four GBU-38s (U.S. Air Force, 2015c). The F-16CJ/DJ was upgraded specifically to conduct SEAD/destruction of enemy air defenses (DEAD) missions, making it capable of more effectively employing the AGM-88. Block 50 and 52s can employ GBU-31 JDAMs, the Wind Corrected Munitions Dispenser (WCMD), and AGM-154 Joint Standoff Weapon (JSOW), and the laser-guided version of the Hydra 70 rockets, the Advanced Precision Kill Weapon System (APKWS).

The A-10 can carry GBU-12 laser guided bombs, AGM-65 Maverick, BLU-1 and BLU-27 cluster munitions and WCMDs, JDAMs, 2.75" rockets, as well as its well-known 30mm cannon.[4] It can carry up to 28 Mk 82 500-lb bombs.

The AC-130 carries a 25mm Gatling cannon, a 40mm Bofors cannon, and a 105mm howitzer. Some have the ability to carry Hellfires, Bushmaster II 30mm cannons, or ten precision munitions (e.g., 35-lb AGM-176 Griffin). Future upgrades may include an SDB and Laser SDB capability.

The B-52 can carry the largest variety of munitions of any U.S. platform, including GBU-31 and 38 JDAM, GP bombs, cluster bombs and WCMDs, laser-guided bombs (LGBs), AGM-86C/D air-launched cruise missiles (ALCMs), AGM-158 JASSM, and sea mines. Ongoing upgrades are allowing the B-52 to go from carrying 12 500-lb GBU-38s to 24, by enabling JDAMs to be carried internally.

The B-1B is able to carry 24 of the 2,000-lb GBU-31s, or 84 of the 500-lb Mk 82s, an astonishing amount of ordnance. It can also carry cluster munitions, WCMDs, JSOW, JASSM, or JASSM–Extended Range (JASSM-ER).

The Hornet and Super Hornet can carry JDAM, Maverick, Standoff Land Attack Missile (SLAM), SLAM-ER (planned), JSOW, LGBs, HARM, and the Advanced Anti-Radiation Guided Missile (AARGM). The Super Hornet can also carry LGBs. It has five external hardpoints that can accommodate air-to-ground ordinance.

The AV-8B can carry GBU, general-purpose bombs, CBU, AGM-65 IR and laser, Maverick, 2.75" rockets, and 5" rockets, and it is being adapted to carry the APKWS.

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4 Aside from the A-10, all of the above aircraft have 20mm cannon.

Attack Helicopters

The Marine Corps AH-1W/Z light attack helicopter provides "close air support, air interdiction, armed reconnaissance, strike coordination and reconnaissance, forward air control (airborne), and aerial escort during day/night operations" (Office of the Under Secretary of Defense [Comptroller], 2016). The Marine Corps has eight active AH-1 squadrons, plus a training squadron and a reserve squadron. A squadron typically includes 18 AH-1 light attack helicopters, though a Marine Expeditionary Unit receives only a detachment of four. Currently there are 128 AH-1W Super Cobras and 39 AH-1Z Vipers. The Marine Corps plans to procure 189 AH-1Z Vipers by 2020, replacing the AH-1W with an aircraft with greater lift and loadout capability. All planned squadrons will be converted to the AH-1Z by 2021. The Hellfire continues to be the principal munition employed by both the Super Cobra and Viper.

Unmanned Systems

Air Force UASs capable of providing ISR and fires include the MQ-1 Predator and MQ-9 Reaper. The Air Force currently maintains 150 MQ-1 Predators, but is not planning any additional procurement. It has 175 Reapers in its inventory, with a plan to procure 361 by 2021. The Predator can carry two AGM-114 Hellfire missiles, while the Reaper can carry four Hellfire, or some combination of GBU-12 Paveway IIs and GBU-38 JDAMs.

Munitions Modernization

DoD is planning to replace the AGM-114 Hellfire with the Joint Air-to-Ground Missile (JAGM); currently all Hellfire II variants are being replaced by the AGM-114R Hellfire II, which has semi-active laser guidance and greater lethality. The Maverick has completed its production run, and DoD plans to replace it with JAGM as well. JAGM is expected to achieve an initial operational capability by 2019. The Navy and Marine Corps are developing an extended-range variant of the JSOW, referred to as JSOW-ER, with an expected range of 555 km. This would be a dramatic improvement over the JSOW's current 120-km range, though both are clearly in a different class than the

12- and 25-km-range Hellfire and Maverick. The Navy and Marine Corps' AGM-84E SLAM and H-variant SLAM-ER is being replaced by the Long-Range Anti-Ship Missile, which will not be able to attack ground targets.

The AGM-88F HARM has received navigation software upgrades through the HARM Control System Modification program. The Air Force will procure 650 of these missiles. DoD is investing science and technology (S&T) money into hypersonic munitions, which could have a dramatic impact on the scenarios considered in this study, if the capability comes to fruition, with applications ranging from strategic missions to SEAD in A2AD environments. Whether a mature capability will actually be produced and procured is fundamentally unknowable at this point.

Information on air-to-ground missiles used by U.S. forces is provided in Table 5.2.

The legacy LGBs Paveway II and III will remain in the inventory through 2020. Laser JDAMs, with semi-active seekers capable of hitting moving targets, have been employed since 2008. DoD believes that, if needed, it could surge production of JDAMs to 10,000 kits per year, though it is unclear whether all ordnance types could accomplish comparable production surges. Though procurement of SDB I ended in 2011, testing is under way on the SDB II, which will have a standoff precision-strike capability.

Information on guided bombs used by U.S. forces is provided in Table 5.3.

Information on cluster munitions used by U.S. forces is provided in Table 5.4.

Targeting

Depending on the specific system, guided bombs and missiles might employ a combination of GPS, inertial navigation systems (INSs), EO, IR, radio frequency (RF), laser, and man-in-the-loop guidance systems. Some cluster munitions, called Wind Corrected Munitions Dispensers (WCMDs), employ INS. GPS and INS may guide the munition to a particular location, but if the target is mobile or the weapon employs individually targetable submunitions, some form of homing guidance

Table 5.2
Air-to-Ground Missiles

Weapon	Weight	Guidance
AGM-114 Hellfire	100 lbs	RF/Laser
AGM-130	2,000 lbs	GPS/man-in-the-loop
AGM-154	1,000 lbs	INS/GPS/IR
AGM-158A	2,000 lbs	IR/imaging
AGM-176 Griffin	35 lbs	GPS/Laser
AGM-65 Maverick	125 lbs/300 lbs	Laser/TV/IR
AGM-84E	1,500 lbs	GPS/INS
AGM-86C	3,000 lbs	GPS/INS
AGM-86D	3,000 lbs	GPS/INS
AGM-88 HARM/AARGM	143 lbs	RF

SOURCE: U.S. Air Force, undated; Jane's Information Group, 2016n.
NOTES: NOTE: INS = inertial navigation system; RF = radio frequency.

is desirable. EO, IR, RF, laser, and man-in-the-loop systems are typical homing guidance solutions. When employing weapons against an opponent with sophisticated IADS, speed and signature reduction are desirable munition characteristics to enhance survivability, making active homing guidance solutions problematic.

The preferred air-to-surface munitions for engaging stationary and moving armored (e.g., tanks) and soft targets (e.g., vehicles, radars) are Hellfire and Maverick missiles, followed by Laser Joint Direct Attack Munition (LJDAM), Dual Mode Laser-Guided Bomb (DMLGB), and LGBs. For personnel targets (e.g., infantry in the open), LJDAM and DMLGB are the preferred munitions, followed by Hellfire and Maverick. For large groups of infantry, Hellfire is not an appropriate munition; flechette rockets, JDAM, and CBUs are more effective. If the infantry are dug in or in a tree line, LGBs become more appropriate than these latter munitions, though LJDAM, DMLGB, and JDAMs remain the preferred munitions. For fortified positions and buildings, DMLGB, LGBs, and JDAM are preferred, followed by Maverick and

Table 5.3
Guided Bombs

Weapon	Weight (lbs)	Guidance
EGBU-15	2,000	TV/IR/GPS/INS
EPW II	1,000	Laser/GPS/INS
GBU-10	2,000	Laser
GBU-12	500	Laser
GBU-12F/B	500	Laser
DMLGB	500	Laser/GPS/INS
GBU-16	1,000	Laser
GBU-24	2,000	Laser/GPS/INS
GBU-28(E)	4,700	Laser
GBU-31	2,000	GPS/INS
GBU-32	1,000	GPS/INS
GBU-37	4,700	GPS
GBU-38	500	GPS/INS
GBU-39 SDB	250	GPS/INS
Viper Strike	40	Laser/GPS
GBU-51/B	500	Laser
GBU-52B	500	Laser/GPS/INS
LJDAM	500	Laser/GPS/INS
Paveway II	1,000	Laser
Paveway IV	500	Laser/GPS/INS

SOURCES: U.S. Navy, undated; Jane's Information Group, 2016o.

Hellfire. For anti-aircraft artillery and SAMs, LJDAM, DMLGB, and LGBs are effective munitions; if they are self-propelled, Maverick should also be considered. HARM and AARGM are clearly the most

Table 5.4
Cluster Munitions

Weapon	Weight (lbs)	Guidance
CBU-78(USN) GATOR	500 AA, AP	GP
CBU-103 WCMD	1,000 CBU-87	INS
CBU-104 WCMD	1,000 CBU-89	INS
CBU-105 WCMD	1,000 CBU-97	INS
CBU-107 WCMD	1,000	INS
CBU-87/B	1,000 AA, AP, AM	GP
CBU-89/B GATOR	1,000 AA, AP	GP
CBU-97/B SFW	1,000 AA	GP
Mk-20 CBU-99/100	500 AA, AP, AM	GP

SOURCES: Jane's Information Group, 2016n, 2016o.

appropriate munition for SEAD missions when there is initial uncertainty over the location of the target.

Surface-to-Surface Strike Capabilities

Marine Expeditionary Fires

Marine Corps artillery includes the HIMARS and the M777 155mm howitzer.

Given the Marine Corps' expeditionary role, Marine Corps infantry units have relatively modest organic fire support capabilities relative to their Army counterparts (though they include significantly more infantry). A Marine infantry regiment is infantry pure, with an 81mm mortar as its largest organic indirect fire asset, compared with an Army BCT's 155mm towed or self-propelled howitzer.

The Marine Corps prefers to develop combined arms capabilities through doctrine, training, habitual relationships, and task organization rather than formal structure, under the theory this creates more flexibility for the Marine Corps to deploy and commanders to employ forces appropriately. Beyond Marine Corps and Naval aviation fire support (discussed above), Marine Corps indirect fire support assets (i.e., the fires triad) chiefly reside in artillery regiments and are task organized as required to support particular missions. By contrast, the Army has no tube artillery or mortars in its active component that are not organic to a maneuver brigade, and the 120mm mortars in its BCTs are not treated as artillery assets.

The most consistently employed Marine Corps form of task organization is the Marine Expeditionary Unit, which, though formed around an infantry battalion, may also include a complement of six AV-8Bs, four AH-1Zs, a 155mm towed-artillery battery, a platoon of four M1A1 Abrams, a platoon of 16 Amphibious Assault Vehicles (essentially an amphibious APC), and a platoon of four Light Armored Vehicles (an lighter version of the Stryker with a 25mm chain gun). Similar Marine Air-Ground Task Forces (MAGTFs) are constructed around Marine infantry regiments—called Marine Expeditionary Brigades—and Marine infantry divisions—called Marine Expeditionary Forces.

The data in Table 5.5 are based on force structure, not inventory of systems. “Active” batteries and systems exclude the 14th Marines (a reserve unit) equipment and units.

Marine Corps surface-to-surface fire support force structure is typically lighter and less diverse than its Army equivalents (there are exceptions). Where the Marine Corps uses HIMARS (wheeled and unarmored) for its surface-to-surface deep fires needs, the Army has both HIMARS and MLRS (tracked and armored). Where the Marine Corps uses the M777 155mm towed artillery (towed by an unarmored truck), the Army uses both M777 and the M109 155mm Paladin (tracked and armored). This general distinction breaks down somewhat in Army IBCTs, which include two M119 105mm batteries (as well as an M777 battery). Moreover, the Marine Corps maintains a nearly a sufficient number of 155mm batteries (23) to assign one in direct support to every infantry battalion in the Marine Corps (24), while Army IBCTs would be able to assign only a 155mm battery in direct support to one out of every three infantry battalions, and the remainder would

Table 5.5
Fire Support Batteries in Marine Force Structure

Regiment	227mm Rocket HIMARS	155mm Howitzer (M777 A2)
10th Marines	0	8
11th Marines	3	8
12th Marines	1	7
14th Marines (RES)	3	7
Active batteries	4	23
Total batteries	7	30
Active systems	24	138
Total systems	42	180

receive only a 105mm battery. The Marine Corps does not maintain any 105mm howitzers (with the exception of a training unit).

The Marine Corps is experimenting with having an artillery platoon provide direct support to an infantry "company landing team," as part of its Expeditionary Force 21 concept for distributed expeditionary operations. Experiments include the employment of M777 155mm howitzers and M119 105mm howitzers (Bacon, 2016). Since the Army is already the proponent for M777 and M119 howitzers, here we touch only briefly on a multiservice 155mm munition development we address more fully elsewhere.

Howitzer

The Multi Service–Standard Guided Projectile (MS-SGP)—a 155mm howitzer–compatible version of the Long-Range Land Attack Projectile (LRLAP), developed for the DDG-1000's Gun Weapon System—is also under development by the Marine Corps in partnership with the Army Armament Research, Development and Engineering Center. The MS-SGP has a range of 70 km and GPS/INS guidance, and a variety of other capabilities, at a cost of $400,000 per round (LaGrone, 2015). High Velocity Projectiles (HVPs), developed originally for the Navy's Electromagnetic Rail Gun (EMRG) and capable of traveling at

Mach 3, are being explored as a more affordable, $25,000-per-round (estimated) alternative to the LRLAP. In 2015, the Army fired a saboted HVP from a Paladin self-propelled howitzer for the first time. The LRLAP, its derivatives, and its alternatives are more fully discussed later in the "Naval Surface Fire Support" section.

Ship-to-Shore Strike Capabilities

Here we address ship- and submarine-based capabilities. The platforms and munitions employed by Navy and Marine Corps aviation are addressed in the above section on air-to-surface capabilities. We divide sea-to-shore fires capabilities into cruise missiles and naval fire support, excluding strategic weapons.

Cruise Missiles

The Tomahawk is a subsonic, nonstealthy land-attack cruise missile deployed on surface combatants and attack and guided-missile submarines. The RGM/UGM-109C/D Block III Tomahawk Land Attack Missile has both a conventional unitary warhead variant (C) and a cluster munition variant (D). The C-variant has a 1,100-kg warhead, while the D-variant drops 166 combined-effects bomblets (Osborn, 2014). They can range 1,700 km from ship and 1,150 km from submarine, with 10-m accuracy. The RGM/UGM-109E Block IV Tactical Tomahawk (TACTOM) is an upgraded version of the C-variant. The TACTOM warhead includes a 99-kg shaped charge and a 138-kg follow-on charge, and can range 2,300 km fired from a ship, 1,500 km from a submarine, with 10-m accuracy. The Tomahawk can employ GPS, terrain contour matching using a radar altimeter, Digital Scene Matching Area Correlator, and inertial navigation systems for guidance. Each round costs $569,000. Nuclear variants (TLAM-N Block II) also exist.

The Navy is expected to continue procuring TACTOMs and upgrading older variants, ensuring this capability remains in the fleet through the 2040s, though until recently the Navy was planning not to procure more and retire older variants by 2020. Recent modernization efforts have included the ability to retarget missiles in flight, enabling a loiter capability, in-flight missile health monitoring, and the ability to transmit a digital snapshot of the battlefield, which enables limited battle damage assessment. Current modernization efforts include the adoption of a multimode seeker, capable of passively using RF emitters while employing an active seeker for target discrimination during its terminal phase, and a new warhead called the Joint Multiple Effects Warhead System (JMEWS; 3,500 kg) that will enable more-effective attacks against hardened targets. In 2006, DoD announced that it had tested electromagnetic pulse payloads for cruise missiles. Recently, the Strategic Capabilities Office sponsored work to reprogram SM-6 and Tomahawk missiles, enabling them to strike targets at sea as well as on land. The Navy's FY17 Budget pointed to development of a Next Generation Strike Capability to replace Tomahawk in the future.

Naval Surface Fire Support

Mk 51 155mm Gun Weapon System and Long-Range Land Attack Projectile

The Mk 51 155mm (6-inch) 62 caliber Gun Weapon System (GWS) is mounted on three *Zumwalt*-class DDG 1000 destroyers. The GWS is embedded in a stealth mount and has other signature-reducing features. It has a 304-round magazine (two per ship) and can fire ten rounds per minute. Concurrent with the development of the GWS in 2000, development on the LRLAP began. The LRLAP is a 230-lb base-bleed rocket-assisted projectile with an extended glide capability, GPS and INS guidance (also capable of IR, EO, and semi-active laser guidance), can be retargeted in-flight, and in testing has a demonstrated range of 117 km and a reported range of 137 km. It can also achieve multiple-round simultaneous impact by firing at different trajectories in rapid, calculated succession. Its glide also enables a near vertical terminal descent, appropriate to urban terrain and selected targets. This is the only round the GWS is designed to accommodate. In mid 2017, the Navy decided to stop procurement of LRLAP due to its high cost.

Contractors independently also developed a 5" version of the LRLAP (see below) and, in partnership with the Marine Corps, the MS-SGP, a saboted version of its 5" round for firing from 155mm howitzers out to a range of 70 km. Because of the LRLAP's high cost, DoD is exploring HVPs as an alternative munition (addressed below).

Mk 45 5" 54/62 Caliber Gun and Hyper Velocity Projectiles

The Mk 45 5" 54 and 62 caliber (mod 0-2 and mod 4, respectively) guns execute anti-surface, anti-air, and ground attack missions. Mk 45 guns are mounted on cruisers (two per ship) and destroyers (one or two per ship). An automatic loader drum carries 20 unguided rounds, which can fired at a rate of 16 to 20 rounds per minute, to a range of 24 km. Munitions include HE, illumination, and smoke. In addition to acute range limitations, historically, the fact that these rounds are unguided and fired from a ship that is itself moving in the water has led to concerns over probable error-in-range, making its employment in a close support role problematic under some conditions.

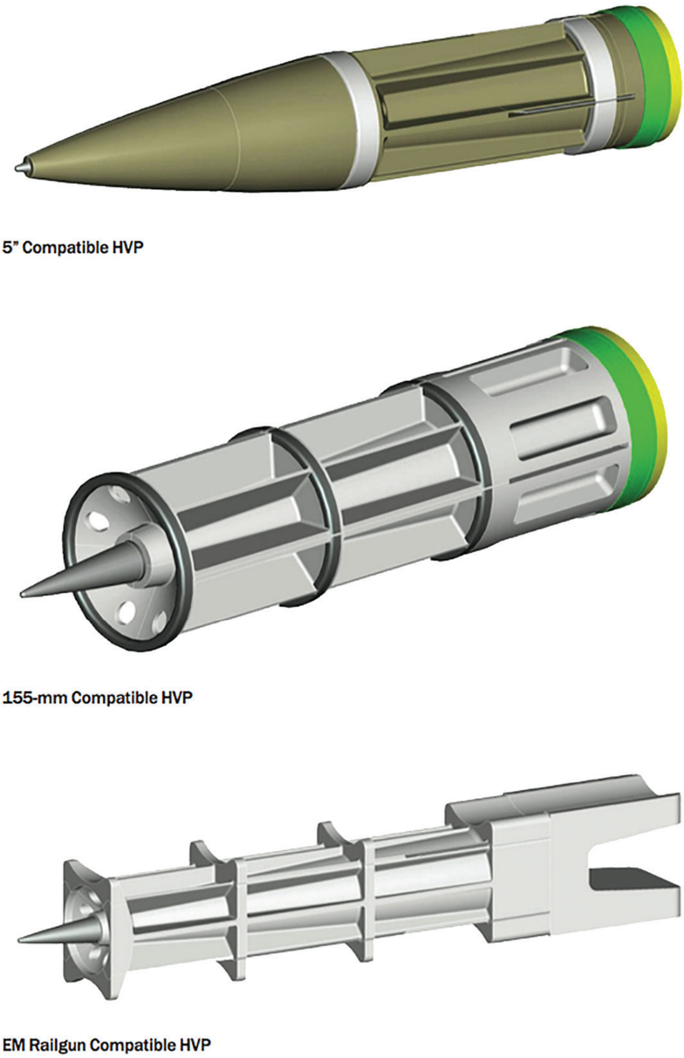
In the mid-1990s, the XM171 Extended Range Guided Munition (ERGM) development program was started to address limits in range and precision. Technical problems arose, development was delayed, and the Navy invested in the development of an alternative solutions. The program was terminated in 2008, at which point developers focused their efforts on creating a 5" version of the LRLAP, addressed above.

More recently, DoD has begun looking seriously at HVPs (shown in Figure 5.2), originally developed for the Navy's EMRG (not to be confused with ERGM). The HVP has a sleeker design than traditional artillery rounds, is guided, and can be fired 74 km from a Mk 45 or 51. A submunition-dispensing variant is in development. The Navy is chiefly interested in HVPs for defense against anti-ship cruise missiles and anti-ship ballistic missiles, though it could also employ them for naval surface fire support. The round is expected to cost about $25,000. The Navy hopes to have HVPs in service by 2025.

The Navy is coordinating with the Strategic Capabilities Office, Army, and Marine Corps, which are interested in firing HVPs from their own 155mm howitzers. The Army demonstrated the ability to fire an HVP from a Paladin for the first time in 2015. Fired from a 155mm howitzer, the HVP can range 31.5 km.

Another munition being explored reverses this technology transfer of naval to land systems. One of the munitions the Navy is con-

Figure 5.2
High Velocity Projectiles



SOURCE: Promotional image from BAE Systems.
RAND *RR2124-5.2*

sidering for its Mk 45s is a naval variant of the Excalibur artillery round. The Excalibur is GPS-guided and capable of ranging 48 km, but costs $68,000. Industry has developed a variant of the Excalibur that can switch between GPS and laser guidance, switching targets, in mid-flight.

Electromagnetic Naval Railgun System

The Navy continues to be interested in developing EMRGs. EMRGs generate an electromagnetic pulse to propel a round forward, rather than using chemical energy as traditional naval guns and artillery do. These weapons would be mounted on large surface ships to provide defense against anti-ship cruise missiles and anti-ship ballistic missiles, and for other missions, such as naval surface fire support.

EMRGs are designed to fire ten rounds per minute, and they can range 93 km with 20MJ or 204 km with 32MJ and travel between Mach 5.9 and 7.4. Sea trials for employing an EMRG are beginning on the USS *Trenton* in 2016. The Navy plans to have an initial operational capability between 2020 and 2025. It plans to install one on a Joint High Speed Vessel in 2016, and another on a *Zumwalt*-class ship in the mid-2020s. Platform integration, energy and thermal management, and barrel life continue to be developmental challenges.

Implications for the Army

Against hybrid irregular adversaries, the joint force will continue to be capable of providing adequate close support and interdiction, including CAS and AI. Though the Air Force is divesting itself of the A-10, it should be recalled that ultimately the A-10 has provided only a modest portion of the CAS in recent conflicts.[5] There are reasons for concern, however. The F-35 is being procured at a lower rate than the Air Force originally intended, and will not result in a one-for-one swap with retiring aircraft. This will likely lead to situations where there is less CAS availability than in recent conflicts. This may be exacerbated by F-35 delays for the Navy and Marine Corps, leaving them to depend on legacy aircraft with falling readiness (fully mission capable) ratings.

5 For a discussion about the A-10 issue, see Matsumura, Gordon, and Steeb (2017).

That said, for most hybrid threats, including ISIL, it may be particularly appropriate to depend more on joint fire support where possible, rather than investing in niche organic fires solutions.

The situation is quite different when we consider a near-peer competitors such as Russia. None of the near-term modernization efforts of the other services are likely to dispose of the A2AD challenge highlighted in our Russia scenario, so the Army's expectation should be that CAS and AI will be only intermittently available during the opening weeks of a conventional conflict. Given that the Tomahawk has recently acquired an anti–surface ship capability, it is possible that there may be conflicting demands for those assets as well. There are S&T efforts under way as an artifact of the Secretary of Defense's Third Offset initiative that could be genuine game changers. But S&T necessarily involves the unknown. Even in the mid term, it is unclear whether DoD will achieve the kind of unchallenged air-superiority that the joint force grew to enjoy during OIF and OEF. For the foreseeable future, the Army will need to be prepared to provide for more of its own close and deep fires than has been necessary since the end of the Cold War.

Counterfire

The counterfire task against hybrid and irregular adversaries will continue to be challenging, but will not result in the kind of catastrophic failure that is possible against Russia. Though ISR is improving, fleeting rocket, artillery, and mortar targets from hybrid and irregular threats will continue to achieve tactical surprise against U.S. forces, making a robust counterbattery fire capability that is organic to Army units of continued importance against this threat class. There are no modernization efforts ongoing within the joint community that will fundamentally change this in the near to mid term. The capabilities of our allies and partners (including those who are otherwise quite capable) against hybrid and irregular threats tend to be weak in this area, and so should also play a role in the development of Army fires doctrine and concepts of employment.

Against a near-peer threat such as Russia that has overwhelming ground fires superiority and sophisticated IADS, the Army will need to have a seamless joint counterfire and SEAD kill chain to maximize the survivability of ground (and air) units. The general trend toward fast, stealthy, precise munitions will help the joint force achieve air superiority, but much of the attrition of enemy ground maneuver units will be left to the Army.

Suppression of Enemy Air Defense

The air defense threat from hybrid and irregular threats will likely render the employment of Army aviation for interdiction challenging. The continued joint investments in ISR, along with the Army aviation community itself employing sound tactics, will ameliorate this problem but not solve it. The probability of encountering MANPADS is only increasing, and future theaters where the United States faces irregular threats will not be as friendly to rotary-wing capabilities as Afghanistan was.

Against Russia, SEAD will become an overwhelmingly important mission that will determine whether the Army receives CAS and AI, including assistance with the counterfire mission. For the near to mid term at least, the joint force will not be capable of managing it without the Army. The Air Force and Navy are taking this problem very seriously, their chief investments being the F-35, AARGM, and HARM control system modifications and associated C4ISR networks. The rest of the joint community has developed a sophisticated common operating picture for tracking and prosecuting targets through Link 16. The Army appears to be on a path to becoming part of that picture, but it is still difficult to judge whether or not the Army is on a path that will lead it to a full integration into this broader joint fires picture.

CHAPTER SIX

Targeting

Introduction

This chapter reviews Army and joint targeting capabilities from the present to roughly 2030. The ability to locate and target enemy forces is essential to delivering timely and accurate fires. During the recent conflicts in Iraq and Afghanistan, the Army's targeting challenges mostly originated in the irregular nature of the conflicts—insurgents were difficult to target because they blended in with the civilian population. In future conventional operations against the armed forces of a hostile nation, there will be different targeting challenges, such as the ability of Army and joint sensors to survive in the face of enemy countermeasures.

The U.S. Army's targeting capabilities in the 2020–2025 time frame show continuity with current capabilities. In recent operations, the Army has relied heavily on its inventory of UASs to locate and track enemy forces. For counterfire capabilities, it has recently started fielding a new generation of counterfire radars that offer incremental improvements compared with its current capability. Upgrades to the Army's air defense radars will improve its ability to detect cruise missiles and UASs, which also has implications for counterfire operations. The service is also modernizing its small fleet of manned ISR/signals intelligence (SIGINT) aircraft for targeting purposes, as well as developing handheld platforms that offer improvements in precision and mobility when locating line-of-sight (LOS) threats.

Looking at the other services, the rapid expansion of F-35 Lightning fleet will expand the formidable ISR capabilities of the Navy, Marine Corps, and Air Force fleets of manned aircraft and UASs. The Air Force and Navy will also continue to grow the capabilities of their fleet of unmanned ISR aircraft. The Air Force will finish replacing its MQ-1 Predators with the MQ-9 Reaper, while the Navy will reach initial operating capability with its MQ-4C Triton UAS. In contrast, investment in the Air Force's and Navy's fleet of manned SIGINT and wide-area radar aircraft is directed toward sustainment of the existing fleet.

In operations against irregular forces or regional powers fielding less than state-of-the-art air defense systems, the Army should be able to maintain its recent success at locating, identifying, and targeting through 2025. Even in these conflicts, though, completion of the SEAD mission by joint forces plays a vital role in enabling UAS platforms to do the work of targeting key enemy threats for attack by Army fires or joint strikes. Depending on the specific opponent, there are vulnerabilities in the Army's targeting capabilities: Its UAS fleets are physically vulnerable, and its counterfire radars are fragile and numerically scarce. However, "lower-tech" (whether state or nonstate) adversaries will generally lack the sophisticated long-distance fires and air defense systems required to exploit vulnerabilities in the Army's ISR system.

In other scenarios, however, the opponent could be a major regional or near-peer competitor operating under the umbrella of a modern IADS. In this case, the opponent could pose severe problems for both Army and joint targeting efforts. For example, the Russian BM-30 *Smerch* MRL can fire from outside the maximum target location range of U.S. counterfire radar, with highly lethal effects. Enemy air defenses may be well equipped to neutralize Army UAS assets. The Army would probably have to rely on joint ISR platforms for assistance, but may find them tasked to other missions, or otherwise of limited assistance. Against well-equipped adversaries, electronic attack and the challenges of integrating Army and joint fires could also limit the ability to target and engage the enemy with sufficient speed to catch highly mobile enemy systems, such as SAM and MRL batteries.

This chapter will review the targeting and ISR capacity available to the U.S. Army in 2025, including current and known future platforms that are planned for fielding in that era. We will then discuss important joint capabilities in the Navy, Air Force, and Marine Corps. Lastly, we will discuss the performance of this ISR and targeting package in reference to the key scenarios used in our study.

U.S. Army Targeting Capabilities to 2030

Short-Range Targeting Systems

Consistent with the service's focus on its ground combat mission, most of the Army's weapons are designed and soldiers are trained to engage hostile threats at ranges from a few meters to a few miles. In these fights, the precision provided by handheld and mounted targeting devices improves the lethality and effectiveness of Army forces. Thus, the Army remains heavily invested in the targeting capabilities of individual soldiers and vehicles. In this section, however, we will focus on systems that provide position and location information (PLI) suitable for directing Army artillery fires. In other words, we will pass over a range of personal reconnaissance systems and sensing enhancements, such as night-vision headsets, sniper scopes, and other equipment that does not acquire and transmit coordinate information for directing indirect fires.

U.S. Army units at present use an array of dismounted rangefinding devices, referred to collectively as "Laser Target Locator" (LTL). The devices include the Vector 21 Binocular Laser Rangefinder, the Mark VII and VIIE Laser Target Locators, the Target Reconnaissance Infrared Geolocating Rangefinder (TRIGR), and the Handheld Laser Marker (HLM). Army equipment databases that we examined refer to generic "Laser Target Locator," and thus we could not obtain information on the prevalence of one system versus another, but the Army has more than 5,000 of these systems in inventory in the Active Army. The systems seem to be of a roughly equivalent: They weigh between 5 and 10 pounds and recognize and provide PLI on targets at ranges up to and beyond 10 km (assuming LOS), although with higher target location error (TLE) tolerances at increased ranges (Jane's Information Group, 2016m). Program Executive Office Soldier publications suggest that they all provide a TLE of about 45 m at a range of 4 km (U.S.

Army, Program Executive Office Soldier, 2014, p. 144). Some of these devices, such as the Mark VIIE, include an embedded GPS Receiver, but most of them must be linked via cable to systems, such as the Defense Advanced GPS Receiver, to know their own position and thus compute target PLI. In addition to rangefinding, these systems generally provide direct view enhanced optics, a digital compass, and some low-light/night-vision target location ability.

According to current plans, the Army will have replaced all these devices by 2025 with the Joint Effects Targeting System (JETS), a similar handheld rangefinder of similar size and appearance to other LTLs. Although JETS is an Army-led program, the Air Force and Marine Corps are expected to join the Army in purchasing this system to universally replace current equipment for forward observers and joint terminal attack controllers. According to Army literature, JETS will generate an improvement in TLE to under 10 m, which could significantly limit collateral damage in urban and otherwise complex human environments, while improving the lethality of joint fires. JETS will be able to digitally interface with “Forward Entry Systems” to directly transmit target information to higher-echelon C2 systems. Unlike prior LTLs, JETS will also be able to generate a laser marker to identify and handoff targets to airborne platforms or provide targeting for laser-guided munitions. The range of the 10-m TLE capability is 2.5 km (U.S. Army, Program Executive Office Soldier, 2014, p. 150).

Although most handheld LTLs currently in use in the Army will be replaced by JETS in 2025, Army IBCTs will continue to field the tripod-mounted Lightweight Laser Designator Rangefinder (LLDR). Currently, the LLDR provides dismounted forces some ability to perform laser marking at long ranges, as well as performing the same rangefinding, optical sight, and night-vision function as smaller handhelds. Although the LLDR weighs six times as much as an LTL, it provides some advantages over current LTLs. In addition to laser marking capabilities, the most recent version (2H) provides improved TLE comparable to the forthcoming JETS today. Army publications claim that the improved TLE (about 0.5 percent), compared with about 1 percent in prior versions, will allow “first-round” artillery effects and reduce the need for forward observers to “talk fire” onto a target over multiple volleys of fire (Robson, 2014). Meanwhile, SBCTs and ABCTs will continue to use vehicle-mounted rangefinding systems, mounted on platforms such as the M2 Bradley. The forward observer version of the Bradley has a common rangefinding system, the Fire Support Sensor System (FS3). FS3 provides video, advanced forward-looking infrared (FLIR) for target recognition in all-weather and 24-hour circumstances, and can provide target PLI at very long ranges (30-m TLE at 10 km) (Raytheon, 2006). As always, terrain limits very-long-distance LOS target recognition, but the FS3's very high levels of current precision helps explain current plans to sustain fielding through 2030.

In addition to LOS targeting, the Army fields the MLQ-40 or MLQ-44 Mobile SIGINT collection and analysis system, known as PROPHET, to the Military Intelligence Company in every BCT. PROPHET is fielded in a set of two or three mobile sensors and a single PROPHET Control Station to BCTs, and in four sets containing eight total sensors to battlefield surveillance brigades. The PROPHET Control Station has beyond-LOS communications via satellite communications (SATCOM) to higher echelons via the Warfighter Information Network–Tactical (WIN-T) network, and can be attached to an HMMWV or Mine Resistant Ambush Protected (MRAP)-type personnel carrier, while the sensor can be used in a mounted vehicle or dismounted manpack. PROPHET operates in the very high-frequency (VHF) and UHF frequency bands and provide some electronic attack capability (Jane's Information Group, 2016c). Although there is very little public discussion of effective ranges, radio spectrum signal reception is associated with short ranges and near-LOS propagation at VHF frequency bands and higher, used by modern military radio communications. The distance from PROPHET's 6-m mast to the horizon is about five miles.

Between now and 2030, it may be possible for the Army to field additional short-range target location systems. For example, it may be feasible to employ relatively cheap "swarming" UASs that could be employed in large numbers against an opponent. The disadvantage of this type of system would be limited payloads and range, but the sheer numbers of low-cost UASs might compensate for the payload limits of individual systems, as well as complicating an opponent's defensive options. In addition to UASs, it may be possible to increase the number of ground sensors (seismic, acoustic, visual, or IR) that could be emplaced by soldiers, delivered by cannons or rockets, or via manned or unmanned aircraft. Given the time lines to develop new systems, any new targeting system (whether U.S. or foreign) would have to be at a fairly advanced state of development today in order to be fielded prior to 2030.

Army Long-Range Targeting Systems: Airborne ISR Platforms

Accurate target location information is essential for accurate indirect fires. U.S. Army artillery units need to receive accurate information on the location of distant enemy forces to execute their mission. Enemy indirect fire and long-distance strike units will frequently assign a high priority to suppressing or destroying Army artillery, and they will attack from ranges and locations hidden from LOS targeting abilities. The timely detection, identification, tracking, and locating of enemy forces, and especially the origin of hostile indirect fire, is essential when fighting a powerful conventional opponent.

Much of long-range reconnaissance is provided by two types of systems: (1) airplanes and other flying or orbiting platforms that observe objects in the air and ground, and (2) ground-based sensing stations that are limited to sensing elevated or aerial objects.[1] Prior to 2001, the Army made heavy use of manned reconnaissance aircraft (helicopters), and also relied heavily on the other services to provide ISR. Since 2001, the Army's large-scale acquisition and wide deployment of UASs has significantly augmented quality and capacity of Army ISR.[2] Today, a handful of key UAS platforms dominate Army ISR, all of which are currently planned to remain in service through 2025. The Army will supplement its UASs with improvements to its small fleet of manned ISR aircraft, undertaken within the Enhanced Medium-Altitude Reconnaissance Surveillance System (EMARSS)

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1 Ground-based sensing stations located at much higher elevations than surrounding terrain, or with very tall antennas, circumvent the limitations of ground-based platforms without flying, but the United States has generally not invested in this approach.

2 For a review of UAS development in DoD and the U.S. Army, see Blom (2010).

program. The last critical element of Army ISR is the ground-based radar stations owned by either the field artillery battalions within a BCT, or by the Army Divisional Headquarters.

The U.S. Army currently operates three primary UASs: The RQ-11 Raven, the RQ-7 Shadow, and the MQ-1C Gray Eagle, an extended range variant of the MQ-1 Predator.

The RQ-11 Raven is the Army's only UAS operating at echelons below the BCT, with multiple systems embedded in every maneuver and some support battalions. One Raven system is composed of three UASs, a ground control station (GCS), two gimbaled sensing EO/IR payloads, a laser illuminator, and supporting equipment. A Raven Team's UAS operator can assemble the Raven system in about five minutes, and programs the mission via the GCS, a hand controller, or laptop. The Raven's battery power and small size (a 4.5-ft. wingspan) allow it a low audio signature that further decreases with altitude (up to 1,000 ft.). However, its flight time of 60–90 minutes limits its operational range to about 12 km—at least if the UAS intends to return to the original operator (U.S. Army, Unmanned Systems Project Office, 2012; Field Manual 3.04-155, 2009). As might be inferred from the robust numbers in which they are fielded, the Raven is not only smaller and quieter, but vastly cheaper to produce ($250,000 per system) than other UASs.

The RQ-7 Shadow serves as the BCT's most capable and durable UAS. In addition to the BCTs, Shadow is used in the CAB. The BCT's Military Intelligence Company or Reconnaissance Squadron fields a UAS Platoon consisting of 22 personnel, four RQ-7 Shadow Tactical Unmanned Aircraft System, two HMMWV-mounted GCSs with associated ground data terminals, four remote video transceivers, and one hydraulic launcher. The system requires eight HMMWVs to transport and is deployed via as few as three C-130 aircraft (in its Early Entry Package formation). A single UAS can sustain operations for nine hours of flight and travel up to 125 km (but only 50 km from its GCS), at altitudes of up to 18,000 ft. The Shadow carries out its primary ISR function, with its laser designator, IR illuminator, and primary EO/IR sensors that provide full-motion video (FMV) during the day and images at night. The Shadow can also act as a single-channel ground-to-air radio system relay, and is compatible with the Army's Advanced Field Artillery Tactical Data System (AFATDS), GCS, and other C2 systems via its Tactical Common Data Link (U.S. Army, 2013, p. 280; Forecast International, 2017d).

The MQ-1C Gray Eagle provides the division and theater ground force commanders with the Army's longest-range and most extensive surveillance capability. A deployed U.S. Army Division will field three platoons of four Gray Eagles each, each platoon served by a company of 122 soldiers in the division's CAB. The significant footprint and cost ($25 million–38 million per platform, about 10 times the cost of BCT Shadow)[3] gained the Army the ability to perform ISR missions up to distances of 500 km, or 1,200 km with relays, and carry advanced ISR sensors, such as synthetic aperture radar (SAR) or other SIGINT packages, along with the expected EO/IR and FMV capabilities, while transmitting data over the Army's WIN-T SATCOM network and performing as a communications relay. Unlike other Army UASs, the Gray Eagle is not limited to an ISR role; it can carry and fire up to four Hellfire missiles during operations.

With regard to future Army UAS development in the next decade, the Army released a "Roadmap" in 2010 intended to guide UAS development, acquisition, and employment through 2035. The Roadmap anticipated the Army sustaining the MQ-1C and the RQ-7 through the mid-term period (2025) and beyond, although with certain capability upgrades. At the time, the Army intended to supplement or replace the RQ-11B Raven with a family of small UASs, including a vertical takeoff and landing UAS. The austere budget environment and changing priorities for the Army since 2010 have forestalled development or deployment of new small UASs (U.S. Army, UAS Center of Excellence, 2010).

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[3] The current unit cost of the MQ-1C vary widely by source; the lowest number for FY16 for production of the UAS alone is $6.6 million. Our number is intended to represent the complete cost of research and development and production of one UAS and its share of related support equipment, ground stations, etc. The upper bound is derived from a U.S. Government Accountability Office analysis (2013, p. 101); the lower bound is a simple average of the total MQ-1C program cost by the number of platforms produced.

Over the 2016–2030 period, the Roadmap expected the MQ-1C (referred to as the "ERMP," for Extended Range Multi-Purpose) to have improved ability to launch, refuel, and rearm without runways; to gain a communications relay capacity; and to gain further improvements in the TLE of its sensor payload. The Roadmap mentioned improved capabilities for the RQ-7 Shadow, such as increased endurance, range, reliability, and payload capacity. As of late 2017, the U.S. Army's Program Executive Office–Aviation has published plans to field an improved engine and continue retrofitting RQ-7B models with the RQ-7Bv2 kit, which adds encryption to Shadow datalinks and provides software upgrades.

By the 2030 time frame, the Army might be able to deploy longer-range, longer-loitering systems that could at least partially compensate for lack of availability of joint platforms that the Army currently depends on for ISR beyond the range of its current UASs such as Gray Eagle. Longer-endurance reconnaissance and targeting UASs would also give the Army the ability to maintain constant surveillance over areas of particular interest or concern.

In addition to its UAS fleet, the U.S. Army operates a fleet of manned ISR aircraft. Generally speaking, these aircraft are converted from civilian passenger aircraft and produced in small batches, sometimes in response to joint urgent operational needs that provide modest amounts of funding (by DoD standards) to solve highly specific problems.[4] The Army has an ongoing EMARSS program of record to upgrade about 25 Hawker-Beechcraft King-Air 350ER aircraft to detect, locate, identify, and track surface targets. The EMARSS program features several different sensor packages, such as Light Detection and Ranging (LIDAR), wide-area surveillance, or communications intelligence (COMINT)/SIGINT packages, which are often individually matched with a particular variant of the EMARSS aircraft. Upgrades from the EMARSS program will allow information

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[4] This paragraph discusses the two largest and most publicly well-known U.S. Army manned ISR aircraft programs, both of which are mentioned in the Army's 2013 Weapon Systems Handbook. This may not account for all Army aircraft in inventory with some ISR capability, but the discussion of these two systems provides an adequate general idea of Army manned ISR capabilities.

acquired by the aircraft to manifest direct into Army intelligence databases through the Distributed Common Ground System terminals onboard (DoD, 2015a, pp. 1103–1111).[5] The Army also has a parallel and seemingly similar fixed-wing ISR aircraft program named the Guardrail Common Sensor, which also operates a small number of small, modified, propeller-driven C-12 aircraft, and which also use various SIGINT, COMINT, and other target acquisition technologies (U.S. Army, Acquisition Support Center, undated-c). Like the aircraft of the EMARSS program, the RC-12 is fielded in small numbers and designed to operate in conditions of uncontested air supremacy.

Army Long-Range Targeting Systems: Radar

While modern UASs are employed primarily to identify objects on the ground, the Army relies on its radar systems to detect and track airborne objects, specifically hostile and unknown aircraft, including UASs, as well as incoming missiles and cannon rocket and mortar projectiles. Both of these approaches to targeting distant forces are important, but Army radars have unique advantages. Hostile artillery and missile units tend to be stationary and vulnerable while they fire, if only for a few minutes. Counterfire radars can quickly detect an enemy artillery or missile unit when it fires. In addition, because Army counterfire radar is physically, electronically, and operationally linked to an Army artillery firing unit (cannons or rocket launchers), targeting information can be acted on with unmatched rapidity. Therefore, field artillery units with effective counterfire radars have a high chance to engage opposing indirect fire units within seconds to a few minutes after they fire.

Army air defense units use their own organic radars to detect aircraft, UASs, and ballistic missiles, including low-altitude aerial threats, such as rotary-wing aircraft and cruise missiles. In the future, it may be possible to employ air defense radars to locate the firing locations of hostile indirect fire systems such as rockets and missiles.

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[5] See also Rosenberg (2010) for an interview with Col. Keith Hirschman, project manager at the time for Army programs that include EMARSS.

The Army is in the process of fielding the TPQ-50 Lightweight Counter-Mortar Radar and its longer-ranged counterpart, the TPQ-53 Quick Reaction Capability Radar. Both are deployed in field artillery battalions within the BCTs. Meanwhile, the TPQ-64 Sentinel Radar is deployed at the division level. Both the TQP-50 and TPQ-53 are new platforms, offering incremental improvements over the previous generation of equivalent systems, the TPQ-36 and TPQ-37 Firefinder Radars. Each field artillery battalion with the BCTs will own two TPQ-53 and four TPQ-50 systems (*Fires: A Joint Publication for U.S. Artillery Professionals*, 2016, pp. 18–20; U.S. Army databases).

The AN/TPQ-50 Lightweight Counter-Mortar Radar is a nonrotating, electronically scanned radar that can detect incoming fire, provide rapid warning messages of impending impact, and provide point-of-origin information. As the name suggests, it is dedicated to locating rocket, artillery, and mortar fires, but with an emphasis on the requirements of combat against light forces and asymmetric threats, which explains its limited range detection range of 0.5–10 km. Specifically, the TPQ-50 emphasizes flexibility, mobility, and a 360-degree search area. The TPQ-50 weighs roughly 500 lbs, can be deployed within 20 minutes by a two-man team and transported by a single HMMWV, with power provided by a trailer-pulled generator or the HMMWV itself (SRC, Inc., 2017). Unlike its predecessor, the TPQ-50 can detect, register, and track friendly and enemy fire simultaneously and provide "did-hit" data for friendly outgoing fire, tracking up to 20 projectiles simultaneously from separate, distributed areas in its 360-degree search sector (Army Techniques Publication 3-09.12, 2015). The TPQ-50 can calculate point-of-impact information concerning friendly fires originating within radar range with similar TLE expectations as for enemy fire (see Table 6.1).

The AN-TPQ-53 Quick Reaction Capability Radar, which is replacing the older TPQ-37, will serve as the Army's primary ground-based capability to detect incoming fires at long range. The TPQ-53 System consists of an active electronically scanned array (AESA) radar transceiver and antennas mounted on an FMTV (Family of Medium Tactical Vehicles) 5-ton truck chassis with an associated trailer-pulled 60kw generator. The TPQ-53 can be air-transported by a single C-130

Table 6.1
AN/TPQ-50 TLE

Weapon	Range (km)	TLE (m)
Mortar 60mm	0.5	50
Mortar 81mm	0.5–0.8	50
Mortar 120mm	1–10	50
Cannon 155mm	1–6	50, or 2% of range
Rocket 122mm	1–10	100, or 3.5% of range
Rocket 240mm	1–10	200, or 3.5% of range

SOURCE: Army Techniques Publication 3-09.12, 2015, pp. 7–8.

in limited manning, mission essential mode. In the mission essential mode, the five-man radar crew is less than half the crew size of its predecessor the Q-37, and is projected to reduce annual operating costs by more than a factor of ten, saving $1.4 million per radar per year, while also improving TLE and emplace/displace times. For protracted operations, the crew size and numbers of vehicles used to support the radar increases. The TPQ-53 can be emplaced and start operating within five minutes of moving into position, and displaced within two minutes. This improvement and the remote operation of the operational control system, which can be separated from the antenna transceiver group by a distance of up to 1 km, drastically improve system survivability. The TPQ-53 can operate in either a full 360- or 90-degree azimuth coverage mode, with the latter offering greatly increased detection ranges (Table 6.2).

In combat, the actual detection and location performance of the TPQ-53 may vary due to environmental and circumstantial factors that affect counterfire radar tracking in general. The Institute for Defense Analyses obtained access to raw data concerning the performance of the TPQ-53 during its initial operational test and evaluation in 2014. The impact of various environmental factors can be seen in the high variance in TLE between the shots being tracked by the Q-53. For example, artillery rounds fired from distances between 12,000 and 14,000 m generated point-of-origin TLE of 25 to 150 m

Table 6.2
AN/TPQ-53 Range and Location Accuracies (1,600 mils coverage)

Weapon Type	Range (km)	Accuracy (m; circular error probable 50)
Mortar light (60mm)	0.5–15	30, or 0.3% of range
Mortar medium (81mm)	0.5–18	30, or 0.3% of range
Mortar heavy (120mm)	0.5–20	30, or 0.3% of range
Cannon light (105mm)	3–30	30, or 0.3% of range
Cannon medium (155mm)	3–32	30, or 0.3% of range
Cannon heavy (8")	3–34	30, or 0.3% of range
Rocket light (80mm)	5–15	30, or 0.3% of range
Rocket light (107mm)	8–50	30, or 0.3% of range
Rocket medium (122mm)	8–50	30, or 0.3% of range
Rocket heavy (240mm)	15–60	30, or 0.3% of range

SOURCE: Army Techniques Publication 3-09.12, 2015, pp. 6–11.

in size.[6] The Institute for Defense Analyses notes variation in TLE and probability of detection from (most importantly) elevation angle of the projectile relative to the ground (quadrant elevation), as well as the angle of the radar search center relative to the projectile's path (aspect angle). Tracking accuracy can also be reduced by interference from other electromagnetic emissions in the area of operation. These specific performance figures may be most important for operations against covert or insurgent forces that might fire single shots and then engage in evasive action. Conventional forces, however, will typically fire in barrages. Although modern military doctrine emphasizes frequent "survivability moves" to avoid counterfire, U.S. Q-53 radars will still have multiple shot trajectories from one location to use in determining point of origin. Nevertheless, the complexity of error incurrence when using counterfire radar introduces uncertainty into the effectiveness of

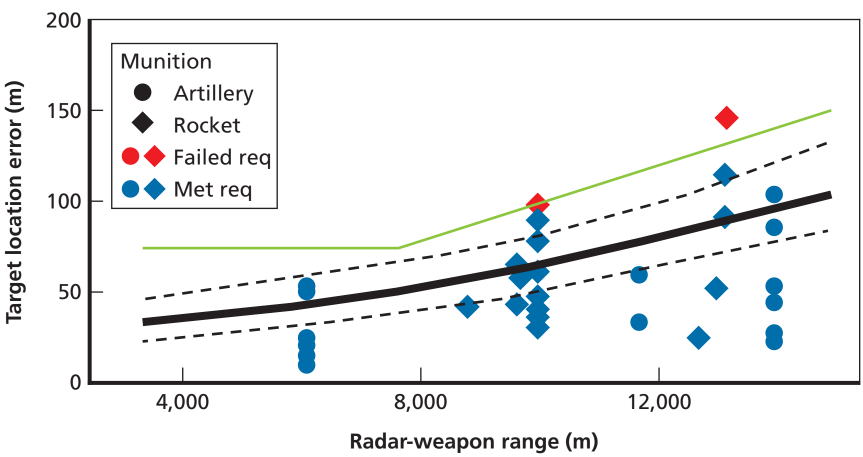
[6] Data are from the Q-53's 360-degree mode. For more information, see Avery and Shaw (2015, p. 26).

return fire, which makes area-of-effect munitions very useful in artillery combat. As Figure 6.1 demonstrates, the accuracy of the target location decreases as range to the target increases.

The last U.S. Army radar of importance to the field artillery is the MPQ-64 Sentinel Radar System, featuring a three-dimensional X-Band, medium-range pulse-Doppler radar that is tasked, in its primary air defense role, to detect, identify, and track fixed-wing and rotary-wing aircraft, UASs, and cruise missiles. In addition to its air defense mission, the Army expects the Sentinel to serve in a counter-rocket, artillery, and mortar role and has ensured that the radar can perform capably against threats of this kind. The Sentinel Radar provides day/night, all-weather, 360-degree coverage; electronic counter-countermeasure (ECCM) capabilities; and provides the information needed to clear and manage airspace for the coordination of fires (U.S. Army, 2013, p. 284; U.S. Army, Acquisition Support Center, undated-a; DoD, 2016d, pp. 913–917).

The radar operates from emplacement on a High-Mobility Trailer (HMT) towed by an HMMWV containing the crew and the

Figure 6.1
Variation in Target Location Error for the Q-53 Radar



SOURCE: Avery and Shaw, 2015, p. 26. Used with permission.
RAND *RR2124-6.1*

MEP-813A 10kw power generator. Additionally, the HMMWV contains the radar control terminal, which can display the air radar picture and communications interfaces. The Sentinel itself transfers data over the Forward Area Air Defense Command, Control, and Intelligence System (FAADC2I) data link to the Army's Integrated Air and Missile Defense Architecture (IAMD), where it may be used to activate air defense firing platforms, such as the AN/TWQ-1 Avenger surface-to-air missile or the future Indirect Fire Protection Capability System. The Sentinel can be emplaced in 15–30 minutes and displace in ten. It is air-transportable with a C-130 aircraft or via sling from a CH-47 helicopter (Field Manual 3-01.11, 2007, pp. A-1–A-5).

While the original MPQ-64 was similar to the TPQ-36 Firefinder radar (Jane's Information Group, 2016d), repeated upgrades in the following decades have expanded its capabilities. The MPQ-64A1 ("Improved Sentinel") added the capability to classify cruise missiles and UASs, improved detection abilities against small and low-flying targets, and expanded the instrumented range to at least 75 km. Critically for our purposes, these changes improved the radar's performance against the same rocket, artillery, and mortar threats addressed by the TPQ-53 and TPQ-50. The AN/MPQ-64A3 Enhanced Sentinel, a newer version being fielded throughout 2016, adds an improved IFF (identification, friend or foe) system and other improvements in Non-Cooperative Target Recognition and overall tracking performance. The Enhanced Sentinel also substitutes a 5-ton FMTV truck for the original HMMWV, which will provide space for new equipment when the Sentinel is integrated with future IAMD systems. Thales-Raytheon Systems, the manufacturer of the Sentinel Radar, claims that the effective range of the MPQ-64 can be increased by either emplacing it on an elevated mast, or by exploiting the modularity of the radar transmitter via additional Power Amplifiers (Thales-Raytheon Systems, 2010a).[7]

Currently, two MPQ-64 Sentinels are authorized for the headquarters battalion of every Army division. In addition, the U.S. Army's air defense artillery battalions contain multiple Sentinel systems per

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[7] *MPQ-64F1* is the contractor's term for the MPQ-64A3. This is clarified in "162.7M for Sentinels to Watch the Skies" (2011).

battalion (U.S. Army, undated), which represent a significant capacity to field robust radar coverage during a high-intensity conflict.

Other Service Targeting Platforms, 2016–2030

Historically, the Army has made extensive use of ISR missions and capabilities owned by other services. It is true and important to note that the Army's total ISR capability has grown dramatically in the post–Cold War era, which leads to a greater degree of independence for the service against lower-tech adversaries. However, the Army can benefit from the continued growth of ISR capacity across the other services. This is especially important against peer competitors, where the task of ISR is complicated by enemy air defenses that other services are more directly tasked and resourced to defeat.

This section will discuss the current state of both ISR assets available today in other services, and known plans for the introduction of future capabilities. The discussion will include unmanned and manned aircraft in both the Air Force and the Navy, categorized according to the schema in Table 6.3, which groups them (for the most part) by their primary sensor package. "National Technical Means" are beyond the scope of this discussion. From among the full list of known aerial platforms tasked to provide ISR, we have selected a limited number of primary platforms for discussion, focused on those that are commonly tasked to provide critical information to U.S. Army forces and assets. Rarely used and small ISR programs, ISR platforms providing highly specialized analysis, and ISR platforms that focus somewhat exclusively on maritime tasks will receive less or no discussion.

The Status of Aerial Radar Platforms

- The Air Force currently operates a fleet of ISR aircraft whose primary mission is to provide relatively low-resolution, but wide-area detection, identification, and tracking of as many moving friendly and hostile objects as possible within a wide battlespace—a concept of operations that dates back to the early years of radar tech-

Table 6.3
ISR and Targeting Platforms by Type

"Primary" Sensor Package	Aircraft	Service
EO/IR	RQ-4 Global Hawk, MQ-4C Triton, MQ-1, MQ-9, Sentinel	Air Force, Navy
SAR	E-3, E-8, E-2, P-8 Poseidon	Air Force, Navy
SIGINT	RC-135, EP-3E, EA-18 Growler	Air Force, Navy
Fifth-generation combat aircraft, multi-sensor	F-35, F-22, RQ-170[a]	Air Force, Navy

SOURCES: U.S. Air Force, 2017; Jane's Information Group, undated-a, undated-b.
NOTE: The RQ-170 Sentinel is not publicly known to be a combat aircraft, but it is presumed to be sufficiently survivable so as to play a role much like the F-35 or F-22 in a joint ISR and targeting strategy.

nology. The Air Force provides this overall airspace tracking and ground surveillance through, respectively, the E-3 Sentry Airborne Warning and Control System (AWACS) and the E-8 Joint Surveillance Attack Radar System (JSTARS). Both programs match very large and capable modern radar sets to a commercial Boeing 707 airframe designed in the 1950s and were purchased in large numbers during the 1950s–1970s (Thompson, 2013).[8]

- The AWACS employs a 30-ft.-diameter AN/APY-2 radar system, mounted 11 ft. above the fuselage, that can provide an all-weather, 360-degree air picture out to at least 250 nmi (for low-flying targets, farther for higher-altitude aircraft) (U.S. Air Force, 2015a). The multimode AN/APY-2 has been upgraded multiple times since its initial deployment. The AN/APY is assisted in building the air picture by an AN/APX-103 IFF interrogator, as well as unspecified electronic support measures (ESM) sensor data ("E-3 AWACS [Sentry] Airborne Warning and Control System," 2017). Communications include VHF and UHF radios, as well as data transmission through a built-in Joint Tactical Information Distribution System (JTIDS) terminal employing the Link-16 data exchange network, as well as through commercial SATCOM con-

8 Of the 800 C-135 aircraft purchased in this era, the 75 still flying are all ISR aircraft.

nections. The E-3 employs a crew of 13–19 airmen, mostly to operate and staff the ISR systems (DoD, 2016b, p. 425; Jane's Information Group, 2016e; "E-3 AWACS [Sentry] Airborne Warning and Control System," 2017). The Boeing 707's 150-ft. airframe allows for a 10–11-hour endurance, which can be extended with in-flight refueling, but comes with drawbacks, including low maneuverability, high fuel consumption, and a limited subsystem supplier availability (Thompson, 2013, pp. 5–13).

- 34 AWACS aircraft were delivered to the Air Force between 1977 and 1984, and 31 remain in service. Most of the remaining aircraft are based at Tinker Air Force Base in Oklahoma, and operated by the U.S. Air Combat Command's 522nd Air Control Wing. The AWACS is currently undergoing an upgrade to the Block 40/45 version, which will provide the E-3 with the previously mentioned satellite communications, ESM upgrades, improved data fusion with off-board information sources, and an improved user interface via the replacement of more legacy software and hardware with commercial off-the-shelf equipment (DoD, 2016b, p. 447; Simonsen, 2007). The Air Force has tried to retire seven of the remaining 31 AWACS in order to fund the improvement program, but Congress has yet to cooperate, thus postponing retirement, although the Air Force maintains it will only be updating 24 E-3 aircraft. The first Block 40/45 E-3s have been delivered, and the entire run is scheduled for completion in FY 2020 (Drew, 2015b).

The Air Force's smaller fleet of E-8 JSTARS uses an apparently similar but downward-looking 24-ft. radome below the aircraft's fuselage, and detects ground targets at distances of at least 250 km (presumably for vehicle-sized targets), as well as some slow-moving aircraft and rotary-wing helicopters. A single E-8 can scan a square box of airspace of about 137 miles per side and communicate the data over JTIDS, although the Air Force has declined to enable the SATCOM capabilities currently being added for the E-3 (U.S. Air Force, 2015b). The E-8 JSTARS airframes are the same repurposed Boeing 707/C-135 commercial jets used by the E-3 but were refitted from earlier production runs, and thus have an average airframe age of 45+ years—ten years older than the AWACS. The E-8 has a similar crewing requirement, similar endurance (nine hours) and airborne refueling capabilities, and similar flight profile to the E-3 AWACS.

The Air Force has developed various plans to confront the rising maintenance and operational costs of the E-8, including a 2007-era plan for an all-new E-10 multimission ISR aircraft that was ultimately canceled, and an engine replacement plan that was canceled after upgrading one aircraft. Following an analysis of alternatives performed in 2011, the Air Force has opted to retire and replace its E-8 fleet, rather than perform additional upgrades (Tirpak, 2015).[9] The Air Force claims that it could save $10 billion through the design and production of a replacement aircraft, relative to the assessed $38.7 billion cost of maintaining (including upgrades) the current fleet of 16 aircraft. The JSTARS replacement lead contractor and base airframe, as of this writing, have not yet been chosen, although the retirement of the E-8 fleet is scheduled to begin in FY19 (Drew, 2015b).

In addition to these Air Force aircraft, the Navy owns several platforms with significant capacity to detect ground targets. The Navy's E2-C and E-2D Hawkeye serves in an AWACS role for a carrier air wing, providing battle management, C2, and ISR services. The E-2D has its own downward-looking 360-degree AESA radar, the Lockheed Martin AN/APY-9, that is claimed to be able to detect targets at more than 300-mile distances, and an ESM system that can "detect and classify targets beyond radar limits" (Forecast International, 2017b). The Navy will produce 25 E-2D Advanced Hawkeyes between FY12 and FY18, as part of a long-term process of replacing its 75-strong E2-C fleet. The primary limitations of the Hawkeye concern availability: It has only a six-hour endurance, and only four E2-C/D aircraft are typically included in one carrier air wing. Additionally, E2s present in a conflict have a primary role of providing C2 for other naval aircraft. The Navy's growing fleet of P-8 Poseidon anti-submarine warfare aircraft possess a similar combination of SAR and ESM, and could also

[9] Modifications to the E-8 fleet are funded in FY17, but appear limited to maintaining current capabilities, in contrast to AWACS upgrades.

be pressed into some role detecting ground targets (Forecast International, 2017c).

The Status of Electro-Optical/Infrared Platforms

Visual images and FMV tend to be more demanding to collect, process, and disseminate than radar imagery and SIGINT, but are the first choice of the U.S. Army for intelligence collection in many missions. EO/IR sensor platforms have received a dominant share of ISR funding, production, and overall capability growth in the Air Force since the 1990s. Although the Air Force retains a small fleet of high-altitude, manned U-2 reconnaissance aircraft,[10] the bulk of the EO/IR ISR air fleet consists of UASs: the MQ-1B Predator, MQ-9 Reaper, and RQ-4 Global Hawk (Table 6.4). As with other ISR collectors, these UASs often have a variety of sensors and are by no means limited to collection via EO/IR, but they are the first choice for Army forces seeking long-range visual imagery collection. The Navy's overall ISR fleet has a much smaller proportion of UASs and EO/IR-focused platforms, which (at least in the latter case) follows from the lower demand for Navy assets to fight in counterinsurgencies and the more complete exposure of ships to SIGINT and radar.

Table 6.4
Key UAS Performance Statistics

UAS Type	Service	Payload (lbs)	Range (miles)/ Endurance (hours)	Inventory FY 2016
MQ-1B	Air Force	540	770/24	150
MQ-9	Air Force	3,750	1,150/27	177
RQ-4	Air Force	3,000	12,300/34	33
MQ-4C	Navy	3,000	8,200/30	0

SOURCES: U.S. Air Force, 2017; Jane's Information Group, undated-a; DoD, 2016a, 2016b

[10] The 32 U-2 aircraft in the U.S. Air Force inventory remain capable of using modern SIGINT, EO/IR, and SAR sensor payloads to conduct ISR. However, they offer no particular advantage over the systems listed here and have certain additional limitations. More information on the U-2 is available at "U-2 High-Altitude Reconnaissance Aircraft," 2017.

The front-line Air Force EO/IR collectors continue to be the well-known MQ-1B Predator UAS, with capabilities very similar to the Army's MQ-1C Gray Eagle. The MQ-1B was developed prior to the Gray Eagle, although it lacks a SAR capability. The Gray Eagle also has a lower payload capacity, carries half the maximum load of Hellfire missiles, and has a correspondingly smaller engine (Forecast International, 2017a). The Predator carries an earlier version of the Multi-Spectral Targeting System found in new UASs, which includes IR sensors, regular and image-intensified TV cameras, and laser designators. The Predator flies slowly but has an endurance of 24 hours of flight and can operate within an 800-mile range. It transmits data over military or commercial SATCOM links to the GCS from which the pilot directs the UAS, which is often within the continental United States (U.S. Air Force, 2015d). The Air Force is in the process of phasing out the Predator in favor of the newer MQ-9 Reaper, but still operates about 150 Predators in FY 2016. The MQ-9 Reaper stands out from its predecessor for its *much* higher payload and larger size. The Reaper, unlike the MQ-1, can use its 3,700-lb payload capacity to equip with JDAMs or LGBs, and/or up to 14 Hellfire missiles. It can fly at higher altitudes and higher speeds and carries a wider range of sensors, including unspecified ESM and a Lynx II SAR. The total MQ-9 fleet is in a period of rapid expansion—reaching at least 177 in only a decade of meaningful production (as of FY 2016) (DoD, 2016c),[11] with plans to expand the fleet to 361 Reapers before the end of this study period.

In contrast to the high level of MQ-9 production, the RQ-4 Global Hawk program is in transition to sustainment of a small, 36-aircraft fleet, with the last platforms scheduled for delivery in 2017 (DoD, 2016a, p. 132; DoD, 2016b, p. 351). The RQ-4 still stands out among ISR aircraft for its unusual deployment flexibility, thanks to its long operational range of 12,000 miles, its high altitude ceiling, and its 30–35-hour flight endurance (U.S. Air Force, 2014). The original Block 20 RQ-4s featured EO/IR sensors and SAR, but have mostly

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[11] See also Tucker (2015) and DoD (2016b, p. 399). The U.S. Air Force may not be the current user of all MQ-9 UASs, which may explain alternate references to U.S. Air Force inventory, such as the fact sheet at U.S. Air Force (2015e).

been retired; more recent RQ-4s feature either an additional “Airborne Signals Intelligence Package” or an improved Multi-Platform Radar Technology Insertion Program that adds Ground Moving Target Indicator (GMTI) capability (Jane’s Information Group, undated-b). The lack of armament for the RQ-4 does not allow it to transition from identifying targets to a strike role. The MQ-9 offers a frequently sufficient ISR and a strike capacity, which may partially explain the end of Air Force RQ-4 production. However, the Navy has selected the RQ-4 as the base UAS platform for its MQ-4C Triton procurement program.

The Navy intends to purchase 68 enhanced MQ-4C UASs, with initial operating capability now scheduled for 2018. It is difficult to clearly discuss sensor variations between the Triton and the Global Hawk. Reports place emphasis on the Triton’s new AN/ZPY-3 AESA SAR, offering 360-degree coverage over very large areas, and automated higher-resolution scan and data transmission of targets of interest, as well as a SIGINT package found on the EP-3E and the ability to descend to lower altitudes to improve the output of its MQ-9-equivalent EO/IR package (Rogoway, 2014). The Navy also intends to supplement the Triton’s long-dwell ISR with a new “UCLASS” (Unmanned Carrier Launched Airborne Surveillance and Strike) UAS, which is currently still in the design phase. The UCLASS is intended to be carrier-launched, lower-altitude, and potentially armed, providing an intermediate-range ISR delivery platform alongside the tactical-focused RQ-8 rotary-wing Fire Scout UAV (unmanned aerial vehicle) (Freedberg, 2014). The Fire Scout UAV’s short operational range and carrier-based deployment renders it unlikely to provide ISR to Army customers, so we omit it from further discussion (U.S. Navy, Naval Air Systems Command, PMA-266 [Multi-Mission Tactical Unmanned Aerial Systems], undated).

One key UAS platform not yet discussed is the Air Force’s mostly recently disclosed and minimally discussed UAS ISR platform, the RQ-170 Sentinel (U.S. Air Force, 2009). No reliable public information is available on the RQ-170’s capabilities. Assuming sufficient data transmission capacity—which is uncertain, because stealthy aircraft face obstacles in transmitting data without compromising low observability—the RQ-170 could play a role similar to the F-35 in plans to collect targeting information on the most difficult targets in highly contested airspace.

The Status of Aerial Signals Intelligence Platforms

The primary aircraft in this category include the Air Force's fleet of 17 venerable RC-135V Rivet Joint aircraft and two specialized Navy platforms, the EP-E3 Aries and the EA-18 Growler. Many aircraft and UASs discussed in other sections, including the RQ-4 Global Hawk and MQ-9 Reaper, also possess some SIGINT capability. Additionally, the F-35 program, which has delivered well over 200 F-35 aircraft to the Air Force, Marine Corps, and Navy through 2016 and will deliver about 100 more annually through most of the study period, has advanced ESM capabilities. The combination of ESM, other ISR systems, and the survivability features of the F-35 render it appropriate for separate discussion. Additional niche programs, such as the Air Force's MC-12W ("Project Liberty"), exist, but will be omitted as not significant to Army operational needs.

The RC-135 is the last of the 1970s-era Boeing 707 derivatives and has had the longest period of operational use, first seeing action in the Vietnam War. The RC-135 specializes in the collection of SIGINT, including COMINT, the electronic transmission of interpersonal communication, and electronic intelligence (ELINT), which determines information about targets based on electronic emissions other than speech. Very little public information is available about the details of these capabilities. While COMINT can obviously reveal information spoken by the targets, both COMINT and ELINT may be used to determine the location, number, and general identity (for example, the type of equipment involved) of collected signals. The entire Air Force fleet of RC-135 aircraft is based at Offutt Air Force Base, with the 55th Air Wing, but has seen deployment and use for every major U.S. military conflict, including OEF/OIF (U.S. Air Force, 2012). The RC-135 operates with the same large, commercial jet profile (135 ft. in length) and similar footprint of 15–20+ crew as the E-3 and E-8, and has an operational range of 3,900 miles.

Since 2006, the RC-135 program has had regular upgrades such that every aircraft is updated every four years (Jane's Information

Group, 2016g); the current profile ("Baseline") seems to be the twelfth in the aircraft's history. The entire fleet received a full replacement and modernization of its engines in the 1996–2006 period. Notable elements from Baseline 11, which appears to be completed for 11 aircraft, and the upcoming Baseline 12, according to congressional budget submissions, involved the following items of interest: a new "steerable beam antenna," work on "precision multi-angle direction-finding capability," "ELINT recorder expansion," "enhanced spatial processing/exploitation," and "enhanced capabilities in dense signal environments." It is also of note that some components, such as cockpit avionics, continue to be replaced or upgraded "to include addressing any obsolescence issues" (DoD, 2016b, p. 285).

In 2017, funding was also provided to continue fielding "Ground Data Processing Systems," although the RC-135 can also share information with other aircraft over SATCOM, in addition to its JTIDS/Link 16 connections and its UHF radios (Jane's Information Group, 2016g; DoD, 2016b, p. 279; "Boeing RC-135 Reconnaissance Aircraft," 2017). The Air Force has spent considerable effort in facilitating the transfer of collected information from the RC-135 to secure locations on the ground in "real time," as would be expected in a mission environment focused on tactical support to troops in Afghanistan. In addition, a recent Air Force article mentions the use of the RC-135 in "cross-cueing" by electronic connection to other air and ground assets (Weisgerber, 2011). This technique can be used to improve the precision of electronic geolocation abilities. Cross-cueing to other aircraft is of particular importance, because of the small number of RC-135 aircraft available. Of the 17 in inventory, Jane's Information Group (2016j) estimates that roughly 60 percent of them are mission-ready at any time. Although the Air Force claimed in a 2008 assessment that the RC-135 will be able to meet mission needs until 2040 (DoD, 2016b, p. 279), outside observers are concerned about the potential for unpredictable and sharp declines in availability (Thompson, 2013, pp. 5, 9). Limited supply of this asset also creates strong incentives for adversaries to invest in risk-acceptant attacks on them.

In contrast to the Air Force's fewer dedicated SIGINT platforms, the Navy has taken the lead in DoD in dedicated aircraft for detecting electronic emissions. The Navy has a small fleet of 12 EP-3 dedicated SIGINT aircraft, converted in the 1990s from the Navy's venerable fleet of P-3 Orion Anti-Submarine Warfare Aircraft, which are currently being replaced by the next-generation P-8 Poseidon. The P-3 is a large (115 by 100 ft.), heavy, slow-flying four-engine turboprop aircraft with a flight crew of four. The EP-3's ISR mission is supported by up to 17 mission crew and an extensive list of sensor systems, including an AN-APS-134 Maritime Surveillance Radar, radar warning receivers, AN/ALR-82 SIGINT receivers, direction-finding antennae, COMINT receivers, and more. A series of upgrades over recent decades added various data fusion and integration packages, and Link-16 connectivity to transmit data over JWICS to remote ground stations for processing (Jane's Information Group, 2016g). The entire fleet of EP-3E aircraft is scheduled to retire by 2020, with some news articles suggesting that UASs will provide the ISR and SIGINT capability offered by the EP-3 (Trimble, 2011). Although the EA-18 Growler is primarily tasked to perform EW activities, it may also replace certain SIGINT capabilities of the EP-3, especially concerning the geolocation of radar emissions, but the EP-3's broader selection of electronic capabilities will not precisely line up with the EA-18's role. Other areas of EP-3E capability may be taken up by the MQ-4C Triton.

The Navy's EA-18 Growler, in contrast to prior airborne ISR platforms discussed, was developed using the airframe of a modern combat aircraft, the F/A-18 Super Hornet, lending it significantly improved survivability and self-defense capabilities but limiting the available space for crew and sensor packages. Developed to replace the prior generation's EA-6 Prowler, the EA-18 bears responsibility for electronic attack across the U.S. Armed Forces, as the last remaining aircraft platform in this role. The E/A-18 Growler has a smaller 60-by-40-ft. airframe and a two-man crew; one person operates the sensors and electronic attack kit (Jane's Information Group, 2016f).

The important features of the EA-18's ISR-related equipment are its AN-APG-79 AESA radar, the AN/ALQ SIGINT receivers, and an ALQ-227 communications countermeasures system. Among other roles, the Navy expects EA-18 aircraft to play a key role in locating advanced IADS radars, such as the Russian SS-21. Articles inform us that "multiple EA-18s" can be used to "generate a weapons quality track vs. emitters" (Majumdar, 2015). Importantly, the AESA radar has a passive detection mode that is claimed to work together with SIGINT receivers to provide passive geolocation of emitters. This provides limited ability using single EA-18s, but the Navy intends to have three-aircraft EA-18 teams work together to achieve geolocating precision sufficient for targeting, relying on time difference of arrival techniques that can be exploited when electronic emissions arrive at discrete points in space at slightly different times. Navy materials on this topic expect the EA-18 to exploit a "Tactical Network Targeting Technology"—essentially a high-bandwidth datalink, retrofitted to the EA-18.[12]

Ultimately, detection and tracking of advanced mobile ground radars will be addressed by a coordinated, networked team consisting of four or five cooperating types of Navy and Air Force aircraft. In addition to its important detection role, assisted by the EA-18's higher survivability and self-defense abilities, the EA-18 will be tasked to use its ALQ-99 jamming pods to disrupt and jam enemy radars, to facilitate their destruction by other aircraft. These jamming pods, whose core components date back to the Vietnam War, will be replaced in the early 2020s by the Next Generation Jammer (Croft, 2008). It should be noted that the EA-18 can be outfitted for a pure ISR mission by equipping an AN/ASD-12(V) Shared Reconnaissance Pod (SHARP), providing it EO/IR capabilities that can independently confirm SIGINT (Jane's Information Group, 2016f).

The Status of Highly Survivable, Low-Observable, Fifth-Generation, Multirole Aircraft in an ISR Role

The other services are currently deploying fifth-generation (stealthy) front-line fighter aircraft to replace the F-15 Eagle, F/A-18 Hornet, and F-16 Falcon in the Air Force, Navy, and Marine Corps (Table 6.5). As of 2016, this effort has resulted in the production of 270 F-35 Light-

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[12] The U.S. Navy FY17 Justification Book (Assistant Secretary of the Navy, Financial Management and Comptroller, undated) refers to "Tactical Network Targeting Technology" as if it has yet to be installed, probably referring to the high-bandwidth data transmitter; Sweetman (2013) refers to the "Tactical Network Targeting Technology" as a processor and algorithm that seems to have been added along with the APG-79 AESA radar.

Table 6.5
Joint ISR Aircraft

Aircraft	Current Inventory	Additional Planned Acquisitions Through FY 2024
EA-18 Growler	138	15 aircraft
RC-135 Rivet Joint	17	None
EP-E3	12	None
E-8 Joint Stars	16	Replacement only
E-3 Sentry (AWACS)	34	None
F-35, Lightning, all types	270	~830 aircraft
F-22 Raptor	197	None
P-8 Poseidon	31	78 aircraft

SOURCES: U.S. Air Force, 2017; Jane's Information Group, undated-a; DoD, 2015c.

ning multirole fighters and 197 F-22 Raptor air superiority fighter aircraft. Although F-22 production has been terminated, over the period of this study the Air Force is currently scheduled to acquire approximately 485 additional F-35As, with an additional 350 of the B and C variants (combined) to be purchased by the Navy and Marine Corps. These figures represent only a portion of the full planned production of 2,440 total F-35 aircraft of all types, although future production (especially over a 20-year future period) should be considered subject to change.[13] Unlike earlier-generation jet fighters, the F-22 and F-35 and are not simply air-superiority and multirole strike aircraft: They have highly capable stand-alone ISR capabilities (U.S. Air Force, Scientific Advisory Board, 2012).[14] Although the sensing systems of these aircraft

13 Cumulative total inventory/production as of FY16 of the F-35 and F-22, as well as the expected volume of final production, are from Jane's Information Group (2016h, 2016i). Projected future production through the end of FY24 for the F-35A is derived from Davies (2016). Projected future production of the F-35B and F-35C through FY24 is derived from Mugg (2016).

14 The ISR capability of the F-35 especially is a common subject of discussion within independent aviation commentary. For an example, see "F-35: Beyond Stealth" (2015).

have the primary purpose of identifying and protecting it from threats to themselves, they will have meaningful ability to detect and track other targets of interest. As far as can be known from public information, the importance of fifth-generation aircraft to Army ISR does not stem primarily from unique or unusually potent sensors, relative to other DoD aerial ISR platforms. Instead, it stems primarily from the ability of the aircraft to penetrate heavily defended airspace in a survivable manner and acquire information without being destroyed. A key question is whether and to what extent this capability can be used to provide Army ground units with targeting data in a timely manner.

The Air Force F-22 Raptor is the most capable air-superiority fighter in the Air Force, designed for exceptional acceleration and maneuverability, as well as "supercruise," i.e., continuous operation at speeds above Mach 1 in a sustained, fuel-efficient manner. Like other fifth-generation aircraft, the F-22 incorporates low-observability features, including radar-absorbent materials, internally carried weapons, and component design that minimizes reflection to avoid detection and tracking by radar. The F-22's twin thrust-vectoring turbofan engines and higher-altitude performance optimization provide superior air-to-air combat performance over the F-35 (and, by extension, any currently fielded combat aircraft).[15] The F-22 Raptor is equipped with a modern AN/APG-77 AESA radar that, while optimized for air-to-air search, can be used in an air-to-ground mode (Jane's Information Group, 2016h). For ISR purposes, however, the F-22's flexibility and performance is limited by its current lack of an EO/IR imaging and reconnaissance system. In addition, although public information on ESM systems are limited, we have found no information suggesting, as is suggested for the F-35, that ESM systems can be used to acquire information on targets. In addition, the F-22's ability to communicate acquired information rapidly back to other aircraft or ground-based C2 stations is inferior to the expected abilities of the F-35 (Reed, 2011). Despite these limitations, the F-22 could have a role in multimission sorties into heavily threatened airspace to identify and strike targets. Although the F-22's AESA radar is described as low-observable by

[15] For extended discussion and comparison of the F-35 and F-22, see Kopp (2007).

some sources (Jane's Information Group, 2016a),[16] all radar emissions increase the probability of an aircraft's detection to some extent. As the most survivable fighter aircraft in the U.S. arsenal, the F-22 is in the best position to incur risk by engaging in active radar search for critical ground targets, strike the target or pass the information along, and return to base.

Despite the higher survivability of the F-22, the F-35 Lightning will serve as the workhorse of all future DoD operations—including ISR and strike missions—in high-threat environments. The F-35 retains the aerial maneuverability of fourth-generation aircraft, while incorporating stealth characteristics, vastly superior avionics and sensors, and real-time onboard data fusion and sharing that allow it to engage and destroy aircraft and ground targets from beyond their detection range. The F-35 possesses a highly capable, solid-state X-band AESA radar with GMTI, SAR, and other modes, and a given look-down range of 120 km to detect a 1-square-meter radar cross-section target (Jane's Information Group, 2016b). In addition, it carries two separate EO/IR targeting systems: an "Electro-Optical Targeting System" focused on identifying threats to the aircraft at long distances, and an "Electro-Optical Distributed Aperture System," using seven IR imaging sensors placed at points across the aircraft to provide continuous display tracking of ground targets. Additionally, articles in open publication describe the F-35 as having a "passive emitter location" capability related to its "Electronic Warfare Suite," including "six apertures" and "three receivers" used by the F-35's EW system, and that "of the various mission sensors," the "EW elements, aided by the AESA antenna, probably would detect the enemy first" (Sherman, 2006).

In addition to its highly capable sensor suite, the F-35's Multi-Function Advanced Datalink, in theory, will allow it to pass targeting information to other, nonstealthy aircraft while maintaining a low probability of detection profile (Mehta, 2013). Near-real-time transfer of targeting information in midair to other aircraft is a critical element of the Air Force and Navy's plans to defeat advanced IADS systems. According to the U.S. Naval Institute, the Navy hopes to pass weapon-

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16 See also "Radar" (undated).

track quality targeting information from the F-35 back to EA-18 Growlers and E-2D Hawkeye Aircraft, and on to F/A-18 Super Hornets, which could then launch long-range standoff weapons against highly protected targets, while the F-35s provide terminal guidance corrections to the weapon from inside the threatened area (Majumdar and LaGrone, 2014). The highly capable sensor suite, stealth characteristics, and (also important) large current and much larger planned inventory of available F-35 aircraft makes it as the most critical manned ISR capability in DoD. In areas defended by advanced IADS systems, fifth-generation aircraft can provide targeting data where other manned *and* most or all unmanned aircraft would be unable to operate.

The Performance of Army and Joint Targeting and ISR Capabilities in Future Scenarios

The final section of this chapter will present an assessment of both the Army and the joint force's expected performance in the ISR realm against several potential adversaries. This section relies on analysis provided both by subject matter experts within RAND, and by U.S. Army stakeholders contacted and interviewed during the course of this study, including during the Fires tabletop game that was held at RAND on June 1–2, 2016.

Operations in the Baltic States

A Russian invasion of the Baltic states presents a grave and intricate ISR and targeting problem that surpasses the resources of available U.S. Army forces, leaving it dependent on the U.S. Air Force and the U.S. Navy to find and track the adversary. In our scenario, the invasion can be assessed as a series of two concurrent assaults against separated U.S. and local forces defending Riga and Tallinn, with a third, largely uncontested assault against southern Lithuania to link up with the Russian Kaliningrad exclave. In the central assault against Riga, U.S. force would seek to track the locations and fires of some 700–1,000 Russian cannons and MRL systems for counterfire purposes. While most of these would travel with the front-line forces, long-range rocket battalions and surface-to-surface missile could fire on the defenders from well behind the front. *Iskander* SS-26 platforms can strike U.S. forces from at least 300 km away, from within the borders of Russia, and will not be subject to point-of-origin location by U.S. surface radars. These long-range strikes would be protected by a formidable, layered IADS with more than 100 SAM batteries capable against Army UASs. Russian brigades possess extensive organic air defenses, with SA-15 launchers that can attack Shadow UASs at their maximum altitude. The limited supply of U.S. Army Gray Eagles are vulnerable to the "second tier" of Russian strategic IADS, the medium-range SA-11/SA-17, as well as very long-range systems such as the S-300/S-400.

The primary UASs the joint force relies on for targeting today (Shadow, Predator, Gray Eagle, etc.) are not expected to be survivable against the Russian IADS, so the U.S. Army will depend on its counterfire radars to detect and locate Russian artillery. Unfortunately, the few TPQ-53 radars available (about 20 between FABs and BCTs, split between three defensive fronts, and perhaps a handful of MPQ-64 Sentinels organic to divisional headquarters) could be intensively targeted by a capable adversary with highly accurate long-range fires and sources of ISR. For ISR resources, Russian UASs and the Russian Air Force will certainly be active in the early days of the war, and Russian ground forces contain capable SIGINT capacity in quantity. Furthermore, the Baltic states contain a dense population of Russian nationals, and Russia has demonstrated the ability in Ukraine to thoroughly penetrate and infiltrate areas near its own borders with human intelligence sources and SOF. During the approach, U.S. counterfire radars may be forced to limit their radiating and take frequent survivability moves, well before Russian forces close to the operational range of their cannons and shorter-range MRL systems (30–50 km). As the main body of Russian forces arrive, counterfire radars face destruction in detail, primarily due to an overwhelming Russian numerical advantage in volume of available fires.

U.S. Air Force and U.S. Navy aircraft, although less overmatched than U.S. Army ground forces, will also face severe obstacles to their ability to conduct ISR. While they are expected to have some ability to locate and track critical Russian targets, the capabilities of their available and survivable assets will be highly limited by Russia's most capable SAM systems. S-300 and S-400 batteries, especially if moved forward from Russia during the conflict, will be able to attack target coalition airspace throughout the Baltic states and Baltic Sea, and will pose a severe threat to all fourth-generation aircraft and UASs, with the possible exception of the RQ-170. The 400-km range of the S-400 will force U.S. Air Force and U.S. Navy ISR aircraft away from ranges where they could precisely target critical systems. Until Russia's strategic SAMs—all of which are mobile—are located and killed, joint ISR will be limited to fifth-generation aircraft, which will face additional threat from the Russian Air Force. In short, Russia will fiercely and capably contest U.S. air superiority and prevent the use of many joint ISR platforms for days, if not weeks. The F-35s and F-22s, as the sole survivable ISR assets, will face an oversaturated target environment. They will need to balance an ISR role in tracking Russian threats with strike and air combat missions, and balance targeting of ground forces with the need to hunt SAM systems.

The use of fifth-generation aircraft to penetrate Russian IADS and locate targets creates an opening to return U.S. artillery forces to a proactive role in destroying Russian indirect fire units and, via ATACMS, even remaining Russian SAMs. However, because of the mobility of key Russian platforms, making this work will require a well-practiced, jamming-resistant concept of operations to rapidly transfer target data from the F-35—not only back to the combat air operations center (CAOC), which falls within current Air Force TTPs, but to U.S. Army BCT command posts. Furthermore, the U.S. Army and U.S. Air Force must plan, train, and practice rapidly coordinating of the use of artillery fire through U.S. Air Force–owned airspace.

Given the severity of Russian air defenses, SEAD will be a very important joint mission, with the Army having an important role both in locating enemy air defenses and engaging them with kinetic and nonkinetic means. Russian air defense systems, whether the Army-level S-400 or the SA-15s in a Russian motorized brigade, are highly mobile. This means that acquisition and firing time lines will be very short. Streamlined procedures that minimize the time required to pass a SEAD target to firing assets (Army or other service) will be essential in these circumstances. Getting the enemy to expose its air defense radars and firing units via the use of decoys and deception should also be utilized. Finally, the Army may need to consider specialized munitions for use against enemy air defenses. An example is anti-radiation warheads for its long-range MLR rockets.

Operations in North Korea

During a conflict with North Korea, U.S. Army ISR and targeting capabilities would be most heavily taxed in the conflict's early stages. The most significant initial challenge for the Army would stem from the multiple calls for use of the limited targeting resources in the small, prepositioned U.S. force. From behind the South Korean lines, the single ABCT stationed in South Korea at the outbreak of hostilities would have six counterfire radars and perhaps 20 UASs with which to track and identify 2,000–3,000 artillery pieces, hundreds of North Korean C2 facilities, hundreds of individual North Korean Army formations, and thousands of additional targets of interest, ranging from potential North Korean SOF forces disguised as civilians, to missile batteries and suspected WMD sites. A single U.S. brigade is not equipped to comprehensively provide ISR for a major war. However, the available TPQ-53 and TPQ-64 radars could locate the point of origin of many of the expected long-range artillery (LRA) attacks on the Seoul metropolitan area. The ROK Army has limited ISR capabilities compared with the U.S. Army and would be dependent on American support, including for counterfire targets.

In contrast, the joint force would likely have more ISR and targeting capacity than Army forces deployed to Korea. At the opening of the conflict, our scenario provides the Air Force and Navy with 160 fifth-generation aircraft with significant ISR ability available. It is likely that one or more squadrons of MQ-9 Reapers would also be stationed in South Korea or Japan. In a matter of days, the Air Force would be able to call on its global ISR fleet. Although some ISR aircraft would be unavailable for operations due to maintenance, and others reserved for ongoing hostilities, a fraction of the Air Force's ISR capacity would suffice to track and identify North Korean targets of interest. As an example of this, the 137-square-mile coverage area of a single

JSTARS aircraft is almost sufficient to cover the entirety of the DMZ on its own. In addition to the small geographical area to cover, the Air Force and Navy would be assisted by North Korea's inability to threaten modern U.S. combat aircraft. The North Korean Air Force is thoroughly obsolete, and its SA-5 and SA-13 SAM systems demonstrated little capability against the Air Force of the mid-1990s, to say nothing of 2017–2030.[17] The North Korean Armed Forces may try to hinder both aerial ISR and strike capabilities by using surface-to-surface missiles to attack airfields in South Korea, and perhaps even Japan, and could use chemical weapons to facilitate this effort. However, North Korea's inventory of missiles capable of striking Japan are limited and inaccurate.

Of course, even given the Air Force's rapid ability to obtain air supremacy, the detection and persistent tracking of thousands of North Korean targets will prove to be challenging. This challenge will be most pronounced at the opening of the conflict, when the highest number of North Korean targets remain intact and Air Force resources are at their fewest. One aspect of the initial ISR challenge worthy of attention concerns the targeting of North Korean LRA engaged in the bombardment of the Seoul metropolitan area. Thousands of North Korean artillery pieces and MRLs are expected to avoid ISR by hiding in fortified underground facilities, emerging only to shoot and rapidly escape back underground, providing the Air Force and Navy a window of only minutes to identify the weapon, pass the target's coordinates to a strike aircraft, and fire on the target. The MQ-9 Reaper (or the Army's MQ-1C Gray Eagle) will be well suited to this task, because it can loiter over an underground facility, identify the LRA as it emerges, and immediately fire on it. U.S. Army TPQ-53 and TPQ-64 radars could also detect and locate LRA fire quickly and accurately enough to allow return fire by the available U.S. artillery forces, but probably only if MRLs and cannon platforms were exclusively reserved for the task.

In the first of our North Korean scenarios, as well as in many possible paths along which a real conflict with North Korea might proceed, the United States ultimately brings significant U.S. Army forces

[17] For an overview, see O'Connor (2010).

to the Korean Peninsula and takes a major role in a combined U.S.–South Korean counteroffensive that seeks to destroy the North Korean Armed Forces. In this scenario, the U.S. Army will be able to bring to bear perhaps 150 or so Shadow and Gray Eagle UASs, as well as about 50 TPQ-53, 10 MPQ-64, and 100 TPQ-50 radar systems, to track and identify threats and North Korean military units in their area of responsibility. Given the expected U.S. air supremacy and our demonstrated ability to destroy targets in the open, North Korean forces will likely be immobile and dug into fortifications and underground facilities.

The U.S. Army should have ample counterfire radar coverage of its area of responsibility to detect and locate incoming fires. It is likely that the ROK forces will ask for support from U.S. radars. North Korean forces will lack ISR capacity and their own counterfire radar, although they might be able to locate U.S. artillery and U.S. Army radars via visual observation by North Korean SOF. To locate other threats, the limiting factor will be the capacity of U.S. UAS operators to pass along targeting information to artillery and the speed at which U.S. artillery can neutralize targets. In direct-fire engagements, forward observers will direct calls for fire to a BCT's tactical operations center, using JETS and LLDR systems to provide "Cat-6" (10-m) accurate coordinates to Army UASs or Air Force and Navy strike aircraft. By the time the United States has established a force of the size stipulated in our scenario, the Army will be able to locate and target anything in North Korea above ground that it might be positioned to fire upon.

Operations in Iran

In the Iran scenario presented earlier, the United States' mission is to force Iran to cease naval, aerial, and missile attacks on shipping and other Persian Gulf targets through long-range strikes and the seizure of outlying island bases. Eventually, U.S. responses could escalate to raids on military targets along the Iranian Persian Gulf coast. The role of the U.S. Army is limited to

- possible long-range strikes across the Persian Gulf with GMLRS (applicable in a few areas) ATACMS, or possibly the proposed M-777ER Extended Range cannon
- defense and protection of U.S. bases in the Persian Gulf
- cooperatively with U.S. Special Operations Command and the Marine Corps, conducting amphibious or airmobile assaults on critical military targets near the Iranian coast.

U.S. Army targeting and ISR needs would correspond to these expected missions. At the very beginning of the campaign, the Army's Gray Eagles and Shadow UASs would be threatened by Iran's air defenses. Iran will soon accept delivery of modern S-300 SAM systems that, as in the Russian case, pose a severe threat fourth-generation aircraft and U.S. Army UAS alike (Mustafa, 2016). Despite this, Iran's IADS network has many fewer assets (both top-tier strategic SAMs and lower-level systems) and a much weaker air force to contest SEAD missions. Above all, Iran has no means to achieve its objectives or force decisive engagements during the first few days of the conflict, while its IADS may remain functional.

Once the U.S. Navy and U.S. Air Force have destroyed Iran's strategic SAMs, U.S. Army UASs should be able to capably locate and track indirect fire targets. However, the Army would be wise to supplement its forces with additional UASs from out of theater. The forces in the scenario will have 12 Gray Eagles and about ten Shadow UAS with which to perform 24-hour surveillance of nearly 1,800 km of Iranian coastline, which is probably insufficient. U.S. Army air defense radars could play a vital role in detecting Iranian cruise missiles and UASs, and U.S. counterfire radars could also assist in providing early warning of attacks, in the event that Iran acquires long-range rockets capable of striking across the Persian Gulf. U.S. Army radars of all kinds should be beyond the ability of Iranian assets to precisely strike or target, although the risk of covert observation or other unconventional methods is not negligible.

Where U.S. Army assets are insufficiently numerous to provide full ISR coverage, U.S. Air Force and U.S. Navy ISR assets should be more than sufficient to locate and strike remaining targets. Again, U.S. Air Force MQ-9 and MQ-1 drones will have advantages: They can loiter at low speeds and high altitude for long periods of time, maintaining continuous surveillance of areas of interest until Iranian mobile missile launchers reveal themselves and firing on revealed targets almost immediately. A useful aspect of U.S. artillery forces in this scenario is the short time they require to fire on Iranian targets with ATACMS or, in some cases, GMLRS, in situations where the primary spotter is unarmed (such as with the Shadow or the U.S. Air Force Global Hawk). In cases where this spotter is a Navy or Air Force asset, it will be critical to establish a highly streamlined process for transmitting target data and establishing fires clearance for the U.S. artillery batteries across the Gulf.

Conclusions

The overall assessment from our scenarios closely adheres to the general conclusions of this chapter. In scenarios where the United States confronts a regional power, the U.S. Army retains proficient ISR capability that can detect, track, and target threats to its forces. Limitations of Army ISR emerge from situations of extreme numerical disadvantage, which can oversaturate the proportionate targeting abilities of small Army forces, or from the enemy's exploitation of classic physical constraints to ISR, via tactics such as the extensive use of underground facilities. Often, the U.S. Army will turn to its organic UASs to provide targeting information, since UASs are the platforms able to acquire targets at the greatest distance from U.S. troops. U.S. counterfire radars and air defense radars will be able to locate incoming indirect fire from enemy standoff fires that should be unable to disrupt their operation. Against a peer competitor, the Army's primary targeting platforms will likely be denied access to enemy territory, or destroyed by enemy indirect fire, when overall force ratios are unfavorable to the United States. These challenges are, in their own way, manifestations of broader force sufficiency and capacity problems—enemy IADS and indirect fires challenge U.S. forces across multiple warfighting domains, and defeating them is important for reasons beyond their impact on the ISR task. However, the U.S. Army nevertheless can adapt to the limitations discussed here.

CHAPTER SEVEN

Capability Gaps

Overview

The U.S. Army faces a broad series of capability gaps to successfully execute the full range of fire missions demanded by the scenarios presented in Chapter Two. There are various approaches to logically organizing and discussing these gaps. Because this report is focused on identifying investments the Army may need to make in materiel, technology, organization, and training across all scenarios, we have chosen to organize this chapter using the sensor-to-shooter kill chain that the Army must successfully complete in order to execute fires missions across all scenarios. Specifically, this chapter is organized in terms of a generic simplification of the fires process that focuses on three essential elements:

- *Sense*. This section focuses on the processes and capabilities associated with detecting and tracking things that either are or may become targets for Army fires, as well as ascertaining their status either pre- or post-strike (e.g., battle damage assessment). It encompasses the broad variety of sensors, Army and joint, that may provide locating information on potential targets, as well as the platforms that carry those sensors; the relevant TTPs; and the Army organizations that operate them.
- *Decide*. This section focuses on the processes and capabilities associated with digesting information received on adversary and friendly units; supporting commanders in assessing operational and tactical situations; relaying such information and assessments

to relevant units; coordinating, managing, and deconflicting fires and directing the execution of fire missions; and the associate TTPs and the Army organizations that execute these processes. In short, it encompasses mission command of fires units in a joint (and allied) fires environment in the broadest meaning of the term, including Army organizational structures for executing mission command.
- *Attack*. This section focuses on the actual fires capabilities themselves: the various weapon systems that provide fires and the details thereof. It encompasses the gun, rocket, and missile systems and their associated capabilities; the vehicles that they are mounted on; the various warheads that they can deliver; the associated systems that support and enable the primary weapon systems; the associated TTPs; and the Army organizations that operate them.

Within each of these three sections, we will consider the implications of each of the scenarios presented in Chapter Two and the key fires missions that are relevant to those scenarios. This allows us to present a cogent and well-rounded discussion—in context—of the capability gaps and potential solutions to those gaps.

Sense

The nature of the problem of detecting and tracking targets for Army fires varies greatly not only with the scenario but also, within some scenarios—especially the Baltic scenario—according to the nature of the targets. We begin with the Baltic scenario because it is the most stressing.

Baltic Scenario

Within the Baltic scenario, there are a series of target classes that present distinctly different challenges and reveal different capability gaps, which we discuss in turn. These target classes are defined by the nature of how they are detected and do not align necessarily with doctrinal constructs. However, this somewhat nondoctrinal, nonstandard classification of targets allows us to focus very clearly on specific sensing capabilities. The target classes are:

- *SEAD Targets.* These consist of the radars, command posts, and firing units associated with Russian air defense systems, both higher-altitude/longer-range and lower-altitude/shorter-range systems. Their critical characteristic is that they are detected primarily by RF emissions either from the various associated radars (search, tracking, and/or engagement) or from the data links and command-and-control communications that interconnect the elements of these systems. These systems are expected to be elusive in the sense that they will carefully manage their RF radiations and reposition rapidly once they have radiated. These targets require an ability to detect and locate these fleeting RF emissions or other means of detecting the target systems.
- *Counterfire Targets.* These consist of Russian fires units that are engaging U.S. or allied units and need to be rapidly destroyed or suppressed. Their critical characteristic is that they are primarily detected by observing their fire and back-tracking it to its place of origin. Like SEAD targets, these systems are expected to rapidly reposition after they have revealed themselves by executing a fires mission. These targets require a U.S. ability to detect and sufficiently track incoming Russian fires so such fires can be back-tracked to their place of origin.
- *General Interdiction/Deep Fires Targets.* These targets include all those interdiction targets not specifically covered by the SEAD or counterfire targets. These can include infrastructure (bridges, rail years, power distribution nodes), various semi-fixed military targets (FOBs, FARPs, supply or ammunition depots), or adversary units not in contact with blue forces. These targets are characterized by not being fleeting in nature (although moving adversary units may be time sensitive) and having no single dominant means of detection—in fact, infrastructure targets will often be already known to commanders and not require "detection" (although sensing of some kind may be necessary to ascertain whether the target needs striking—for example, is the bridge already down?).

Other targets may be identified from imagery or by electronic emissions, by human intelligence or allied resistance elements, or by reconnaissance or special forces units operating relatively deeply in adversary territory.

- *Supporting Fires Targets.* These targets are those fired upon in direct support of blue ground forces. This encompasses all forms of support: direct and indirect fires, suppressing and covering fires, etc. What characterizes these targets is that they are identified and located primarily by ground forces in contact with the adversary.

Sensing SEAD Targets

The primary means of detecting SEAD Targets is via their RF emissions, either from their radars or from the communications links that in many cases interconnect the components of an air-defense system. As highlighted in Chapter Six, the Army has essentially no capability to detect such RF emissions currently and projected investments through 2045 are not expected to change this. Ground-based ESM systems such as PROPHET have limited range and are unlikely to operate close enough to adversary SAM systems to detect their emissions. The Army manned and unmanned platforms carry sensor payloads that are primarily focused on EO/IR or on SIGINT signals associated with finding, fixing, and finishing the kinds of targets pursued in irregular warfare. These systems are not designed to detect, classify, or accurately locate the specialized waveforms associated with SAM system radars or the digital data link communications that interconnect the elements of a SAM system. An even more fundamental problem is that Army airborne platforms will simply not survive for long flying over the robust network of Russian air defense systems.

This means that—lacking a dedicated investment in this capability by the Army—targeting for SEAD targets will have to come from the joint force. As SEAD is an essential Air Force (and Naval aviation) mission, these services bring a significant and dedicated capability to detect and locate SEAD targets (as described in Chapter Four). Furthermore, because this is such an essential mission for Air Force and Naval aviation, the Army can count on these services continuing to invest in and maintain effective capabilities for detecting SEAD targets—failing to do so would amount to Air Force and Navy aviation forfeiting air dominance. Because the Army can rely on the joint force to develop the capabilities to detect and locate SEAD targets, there is no need for the Army to invest in such capabilities for the purpose of conducting fires against SEAD targets;[1] rather, the Army should invest in capabilities to obtain the necessary data from the joint force. Such investments are further discussed in the "Decide" section of this chapter.

Sensing Counterfire Targets

The essential capability for this class of targets is being able to detect and track the adversary's incoming fires. As discussed in Chapter Six, the TPQ-53 will be the Army's primary capability in this regard through 2045 and beyond. Furthermore, counterfire is mission specific to ground forces—air and naval forces do not have capabilities designed to detect the majority of ground-to-ground fires that concern the Army.[2] So the primary question is whether the TPQ-53 is well suited to meet the needs of the Baltic scenario. In addressing this question, there are two areas of potential concern: detection range and performance in the face of Russian EW.

The concern regarding range is due to the fact that current TPQ-53 is not assessed to have sufficient range to counter-target the Russian BM-30 *Smerch* rocket system. As there are relatively few *Smerch* systems compared with the overwhelming preponderance of shorter-range *Grad* and *Uragan* rockets and even more numerous Russian cannons, this capability gap is not as critical as ensuring there are enough TPQ-53 systems to both deal with the volume of shorter-range Russian

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[1] However, the Army may desire to invest in more limited ability to detect SAM systems to enable the self-protection of Army aviation platforms, but such radar-warning systems that enable avoidance or evasion are generally much simpler and lower cost than systems designed to detect SAM systems at longer ranges and provide sufficiently accurate locating information to enable engagement of SAM targets.

[2] A possible exception may be the ability of *Aegis*-class ships to detect the longer-range rockets such as *Iskander*, but even that would require stationing of such ships in the waters in the vicinity of the *Iskander*'s target—something rather unlikely in a Baltic context.

fire systems and survive (further discussed below). However, as *Smerch* can in principle be ranged by the U.S. GMLRS rocket system, it would be desirable to have a counterfire sensor with sufficient range to counter-target *Smerch*. To this end the Army should investigate options for extending the range of the TPQ-53, or perhaps the TPQ-64 Sentinel radar. Manufacturer literature for the latter suggests that the TPQ-64's range can be extended by "simply" providing additional power to the transceiver (Thales-Raytheon Systems, 2010b). If this were actually true, this would potentially offer a relatively lower-cost path to addressing this capability gap (and perhaps such a modification can also be made to the TPQ-53; using the TPQ-64 as a counterfire radar for *Smerch* would also require corresponding TTP and perhaps even organizational changes).

The second concern is the performance of the TPQ-53 in hard EW environments. As described in Chapters One and Three, the Russian EW capabilities are extensive. To preclude a potential capability gap in counterfire, the U.S. Army must ensure that the TPQ-53 performance is uncompromised in any likely EW environment or, alternatively, that mitigation strategies exist.

Finally, it is important to highlight that the Russian Army will almost certainly consider the TPQ-53 a high-value target and go to great lengths to locate and rapidly destroy it whenever a TPQ-53 radiates. The TPQ-53's very rapid two-minute displacement time will greatly enhance its survivability (assuming Army units train to realize that potential ability). Nevertheless, to be effective in the counterfire mission, TPQ-53 must collectively spend a lot of time radiating and invariably will sustain losses. This highlights that while the Army has invested in a capable system, the Army must also invest in sufficient numbers of TPQ-53s to replace expected losses in a Baltic scenario—and given the short time line associated with a Russian invasion of the Baltics, this means providing deployed units with battlefield spares, not replacement TPQ-53s to be shipped from the continental United States.

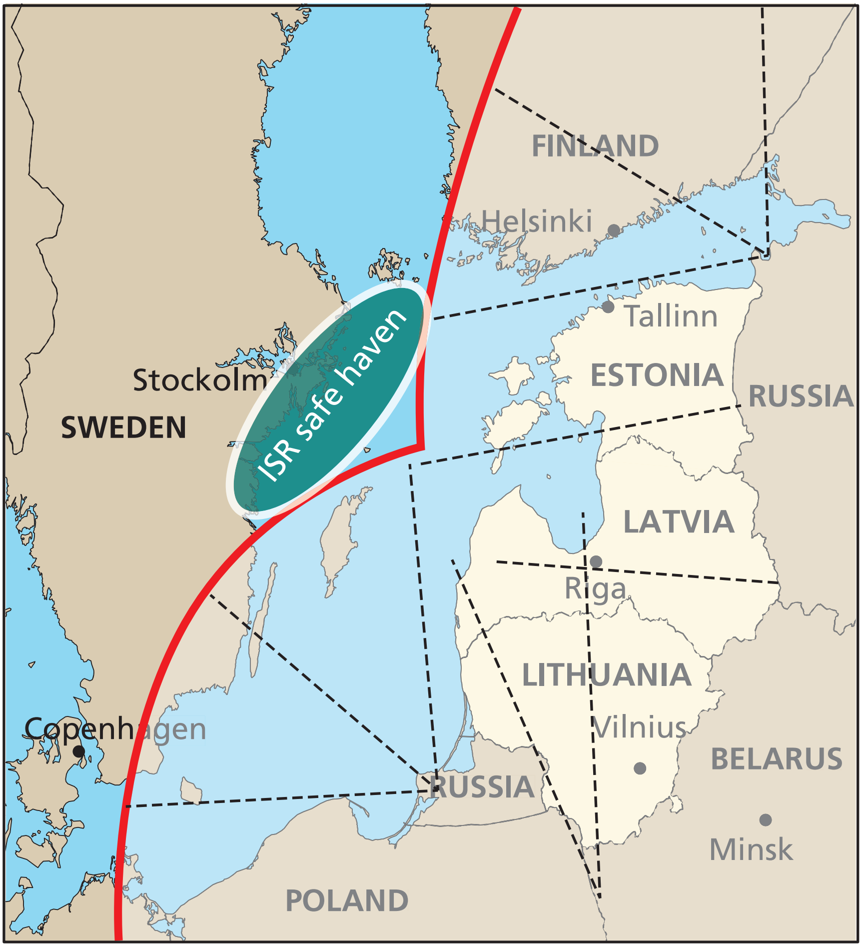
Sensing General Interdiction/Deep Fires Targets

The broad range of targets in this category can be divided into those that need to be detected and located (e.g., adversary formations, FOBs/FARPs) and those that do not need to be detected and located (e.g., infrastructure such as bridges)—although even the latter may have sensing requirements associated with determining the appropriate time to strike them. Army abilities to detect and locate (or even observe) these kinds of targets will be exceedingly limited in a Baltic scenario: Army manned and unmanned airborne platforms are not designed to survive the dense Russian IADS, and the Army does not have, nor plan to acquire in the future, systems capable of detecting such targets at long-range from their electronic emissions (or by other means). The Army will have to rely on joint and national systems to provide these capabilities. Unfortunately—unlike the case for SEAD targets—it is unlikely that joint and national capabilities will be able to meet the Army's targeting needs.

Let us consider first the joint systems that the Army traditionally relies on for such targeting: manned platforms such as RC-135 Rivet Joint, E-8 JSTARS, U-2, P-3/EP-3 Orion, P-8/EP-8 Poseidon, and a variety of unmanned platforms such as the MQ-1 Predator, the MQ-9 Reaper, RQ-4 Global Hawk, and the RQ-170 Sentinel. Most of these platforms will not contribute significantly to detecting and tracking targets of interest to the Army because the platforms do not have long-range sensors and—with the possible exception of the more-advanced UASs—are not survivable against the Russian IADS. The primary platforms that carry sensors that are capable of detecting and locating electronic emissions at long-range—specifically Rivet Joint, JSTARS, and (when loaded with appropriate sensor payloads) U-2—are aluminum-skinned aircraft that are highly vulnerable to Russian long-range SAMs. To stay out of the range of systems such as the SA-21b ("S-400"), these aircraft will be forced to operate in an ISR safe haven area that is nearly over Stockholm, as illustrated in Figure 7.1.

Operating from this safe haven area, ISR aircraft will be approximately 300 miles from the area along the border of the Baltic states and Russia—the region in which most of the targets of interest are likely to be found. At these extreme ranges, even the most accurate lines-

Figure 7.1
Baltics Safe Haven Area for Operating Large ISR Aircraft



SOURCE: Ranges based on data from Jane's Information Group (2013).
RAND *RR2124-7.1*

of-bearing produced by these platforms will correspond to large error ellipses and will not be able to produce locating information of sufficient precision to be used as targeting data for Army fires.

Locating data on targets in this category will predominantly have to come from more-survivable aviation platforms such as the F-22, the

F-35, and the next generation of Air Force and Navy UASs. The F-22 and F-35 in particular are to be equipped with capable sensor suites and will (when fully fielded) have the ability to exchange and integrate data across aircraft. But ISR is a collateral mission for these aircraft, not a primary mission. National space-based systems are the other potential source of targeting data. However, Russia (and China) have openly developed both hard-kill and soft-kill capabilities to challenge U.S. space-based ISR systems. While we are unable to make long-term predictions as to the overall effectiveness of Russian efforts to counter our space system, it is fair to assume a potentially significant level of degradation in the U.S. space-based ISR capabilities. Furthermore, this paucity of ISR affects the entire joint force. So the land component commander's demands for ISR will have to compete with those of the other component commanders' and the joint commander's own priorities for ISR.

In short, the Army will have essentially no organic capability to reliably detect or track targets in this class. Furthermore, in a Baltic scenario, ground forces will have to compete with other priorities for very limited joint and national ISR assets. Because the primary providers of ISR will be fifth-generation aircraft and national systems, the key investment the Army can make is to ensure it is able to receive and exploit ISR derived by these systems (a topic further developed in the next section, on "Decide").

Supporting Fires Targets

Targets in this class are those identified and located primarily by ground forces in contact with the adversary. The Army has a broad variety of systems and processes designed to detect and suitably locate such targets. These systems include a variety of laser and IR rangefinders and optical systems for use by both mounted and dismounted troops (see Chapter Six). We assess that Army plans for such systems will broadly provide the capabilities needed by troops on the ground to generate the targeting information needed to direct supporting fires. There is perhaps one information gap, which is how well these systems will perform in the face of potential Russian countermeasures to these systems in the form of obscurants, jammers, and/or blinding systems.

Appropriate field-testing of Army systems (current and developmental) should suffice to address this information gap.

North Korean Scenarios

North Korean scenarios present a very different sensing problem than Baltic scenarios. There is no significant IADS threat, and we estimate that the full suite of Army and Joint ISR capabilities can be brought to bear on the problem, with minimal risk (after the initial SEAD campaign) to fourth-generation aircraft, including ISR platforms. The full range of national ISR capabilities should also be available. The primary challenge in North Korean scenarios—especially scenarios in which North Korean shell Seoul from the Kaesong Heights—is rapidly generating high-precision targeting information on approximately 3,000 hardened firing positions.[3] While the Army and the joint force have effective systems for locating these firing positions (e.g., counterfire radars, UASs with narrow- and wide-area FMV, Moving Target Indicator, etc.) and sufficient numbers to blanket the Kaesong Heights with such systems, neither the Army nor the joint force has ever rehearsed integrating all the sensors and conducting rapid targeting on this kind of scale. This is a gap here in Army and joint planning and training for this challenging mission.

Iran Scenarios

The Iran scenarios call for limited, precision strikes by Army long-range fires (GMLRS, ATACMS, and their successors). In this scenario, targeting is provided by the joint force and/or national means through the same deliberate joint targeting process that would assign targets to Army fires units. While that targeting might be derived from the Army's long-range airborne sensors (Gray Eagle or EMARSS), these mostly like would have been operating not in direct support of the Army firing units, but rather as elements of the large joint constellation of ISR platforms controlled by the Joint Forces Air Control Center. There are no significant sensing gaps in the Iran scenarios.

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[3] Army artillery may also lack munitions capable of neutralizing the hardest of the North Korean artillery emplacements.

Iraq/ISIL Scenarios

These scenarios represent similar sensing and targeting problems to those the Army experiences today. DoD has spent the past 15 years developing ISR systems (including FMV, SIGINT, EO/IR, Moving Target Indicator, SAR, and multispectral systems) exquisitely tuned to detecting and tracking irregular forces, and U.S. forces have become very adept at doing so, especially when such forces mass or otherwise operate as a fighting force. The only potential capability gap in sensing for Iraq/ISIL scenarios might arise in the future if the Army were to divest itself of the capabilities that it has acquired over the past 15 years.

On the other hand, while the Army itself may not have any sensing capability gaps in this scenario, the Army and its postulated coalition partners currently do not have the capacity to exchange targeting data and data on the locations of coalition forces. That gap would limit the Army's ability to support our partners and would slow the pace of coalition operations.

China/Pacific Scenarios

These scenarios feature two kinds of fires: very-long-range fires against ground targets, and medium-range fires against ship targets. The Army has essentially no organic capacity to detect and/or track either kind of target. But as these targets would be assigned to the Army to fire on by a deliberate joint targeting process, detection and tracking would be provided by joint force ISR capabilities, which are quite robust, especially with regard to ships. Thus, the Army would not be called on to generate its own targeting data for such fires. Thus the lack of organic Army sensing capabilities against these targets is not a problem. As such, there is no Army sensing gap in the China/Pacific scenarios.

Decide

The challenges of exercising mission command of Army fires units vary greatly with scenario. The challenges are driven primarily by several factors: the level of jointness, the degree of allied interoperability, the

EW/cyber environment, and the vulnerability of key nodes the Army depends on to exercise mission command. These factors shape the difficulty of assembling and sharing a suitable operational picture, as well as coordinating, deconflicting, and executing fire missions. The Baltic scenario has complications for all three of these factors, creating the most stressing environment for mission command, and is the natural starting point for our discussion of gaps.

Baltic Scenario

As highlighted in previous chapters, the Baltic scenario has distinctive characteristics that affect the ability of Army commanders to exercise effective mission command of fires units:

- *Jointness.* The intrinsically joint nature of the Baltic fight (driven by the very capable Russian IADS) introduces two complications into Army mission command of fires units. The first is a dependence on joint and national sensors for targeting certain kinds of fires (especially again SEAD targets and deep interdiction fires; see previous section). The second is a need to deconflict airspace to conduct fires (especially deep fires).
- *Allied Interoperability.* Allied units are essential to the Baltic scenario, not only for the geopolitical message of NATO unity, but also because allied units bring capabilities—including fires—that are much needed on the battlefield. However, integrating these units effectively requires interoperability at a variety of levels for the alliance to exercise effective mission command.
- *EW and Cyber Resilience.* As described in Chapter Three, Russian forces bring an extensive collection of electronic warfare capabilities, with EW units embedded even down to the brigade level. These systems are designed to jam U.S. and allied communications. Furthermore, Russia is believed to have very capable offensive cyber capabilities, and their forces are expected to attempt attacks on U.S. unclassified and classified information systems.
- *Vulnerability.* During OEF and OIF, U.S. forces exercised mission command from fixed locations that were considered secure, with the greatest risk coming from occasional mortar, suicide, or

insider attacks. In a Baltic scenario, the situation is quite different: Russian forces have a variety of weapon systems quite capable of destroying any U.S. command post in the region—if they can locate it. And the Russians have sophisticated ESM systems for rapidly locating U.S. electronic emissions. U.S. command posts will need to adapt to this environment, or they will not survive long enough to exercise mission command.

To the challenges posed to mission command by the above factor, we must add one other element:

- *Organization and Structure of U.S. Army Fires.* The current organizational structure of the U.S. Army places the majority of fires units within brigades. The demands of the Baltic scenario will require effective use of Army fires for missions above brigade level and the coordinated massing of fires. The Army needs to potentially rethink how fires should be organized for the Baltic scenario.

Each of these topics is discussed further in the following subsections.

Jointness

The previous section, "Sense," elaborated on the Army's reliance on joint and national systems for targeting. This requires that Army systems be capable of receiving targeting information from airborne platforms—specifically ISR information collected by survivable platforms such as the F-22 and F-35, as well as national systems. By *capable*, we mean both a technical capability of exchanging targeting information in near-real-time and established, trained, and exercised joint TTPs for doing so. Our research has not identified an effective data-path from these aircraft (or potential future stealthy UASs) to Army command posts and firing units. The inability to reliably and quickly share airborne ISR data (especially from fifth-generation aircraft) is a critical capability gap. Failing to address this gap will deprive the Army of information already collected (at great expense and risk) by the joint force. It will be prohibitively expensive for the Army to develop and deploy its own survivable ISR capabilities; it will be relatively inexpensive for the Army to develop and field capabilities that tap into existing ISR data. What is required is that future developments of existing systems, such as Command Post Of the Future (CPOF) and AFATDS, be focused on integrating them with appropriate Air Force and joint systems so they can seamlessly receive any and all ISR data generated by fifth-generation aircraft. Furthermore, the CAOC data streams already include fused national sensor data (as classification allows); thus, seamlessly tapping into CAOC data will provide an additional path for receiving national sensor data, especially for units that are not equipped with Distributed Common Ground System–Army (DCGS-A). It is not enough to field these capabilities, but appropriate joint TTPs must be developed, trained to, and exercised.

The second critical joint capability for the Army in a Baltic scenario is the ability to deconflict Army fires, especially for long-range systems such as GMLRS and ATACMS. These systems will often fire through airspace that is controlled by the Air Component Commander, requiring that airspace to be cleared before Army units can fire. Furthermore, Russian SAM, missile, rocket, and artillery systems are generally designed to enable "shoot-and-scoot" and/or "radiate-and-scoot" tactics, which means that fires against these targets must happen quickly to be effective (as opposed to creating craters in the dirt). This puts a premium on the ability to deconflict airspace and clear fires rapidly. The wargame conducted at RAND indicated that the necessary technical capabilities—specifically AFATDS and the Tactical Airspace Integration System (TAIS)—exist to support this function, and that the appropriate coordinating organizations (i.e., Battlefield Coordination Detachment) also exist. However, all participants (Army and Air Force) were in agreement that coordination at the level required by a Baltic scenario (complex airspace, complex fire missions, very short time lines) has not been exercised. Furthermore, there was disagreement as to whether the existing TTPs would be adequate for this situation. Until these capabilities are exercised, uncertainties about the TTPs resolved, and all parties are fully trained, air space deconfliction in a Baltic scenario remains a capability gap.

Allied Interoperability

The Baltic scenario includes fires units from NATO allies. Their participation is both an embodiment of NATO solidarity and also represents a valuable military contribution in view of the superiority of Russian firepower. As allied ISR and mission command capabilities lag U.S. capabilities, they will rely on the United States for targeting, deconfliction, and mission command for any allied fires that are not executed in immediate direct support of their own national ground forces. This will require that Army mission commands systems (such as CPOF, AFATDS, and TAIS) interoperate with NATO allied systems. We expect this will require accommodations by both U.S. and allied national systems: Future increments in the development of both U.S. and allied systems will need to work toward a seamless, near-real-time capability to exchange data and transmit mission commands. This will involve coordination not only of data exchange particulars (formats, protocols, etc.), but also of coordination of the underlying communications systems through which the data will be exchanged. Full exploration of what is required to provide NATO interoperability in this regard is beyond the scope of this report. However, the present inability to seamlessly exchange data and commands is key capability gap.

Electronic Warfare and Cyber Resilience

In a Baltic scenario, the Army will face an EW environment unlike any other it has faced to date. Russian combat units down to the brigade level are equipped with EW capabilities that will challenge most Army communications systems and may even put at risk the Army's current reliance on space-based position, navigation, and timing (PNT) systems. To deal with this environment, the Army today has several gaps that it must address:

- *Information gap.* The Army must test its current communications and information systems (including PNT-related systems) in realistic EW and cyber conditions to better understand their vulnerability to jamming and cyber intrusion. Such testing is essential to determining the precise capability gaps that need to be addressed with material solutions and to understand what opportunities there may be for TTP workarounds.

- *Capability gap.* Resolving the information gap is expected to lead to specific capability gaps in communication and information systems. Pending completion of such testing, we cannot identify specific gaps at this time.
- *TTP gap.* Over the past 15 years, Army units have become reliant on extensive use of comminations to enable precise and lethal operations down to the company level. The Army has achieved a true information revolution that puts detailed red- and blue-force data in the hands of individual soldiers, and enables them to conduct digital information exchange with other units and even aircraft overhead. The communications and information they have come to rely on may be denied to them in a Baltic war. TTPs need to be either resurrected or created for how the Army will fight in a communication- and/or PNT-denied environment. These TTPs should be informed by test data on the potential vulnerability of existing and projected communications and PNT systems.
- *Training gap.* Army units need to train in an environment in which the information they are used to having is no longer available. For example, in a PNT-denied environment, artillery units may need to rely on older methods survey and registration techniques. The Army is just beginning to include the effects of electronic, PNT, and cyber warfare in training events. This needs to become a standard element throughout the training pipeline and reflect the latest information on expected EW and cyber effects and the most up-to-date TTPs.

Vulnerability

In the Baltic scenario, Russian forces can rapidly strike any U.S. command post in the region that they are able to locate. In Ukraine, Russian forces demonstrated an ability to geolocate a variety of RF emissions and rapidly launch large fires barrages at these locations. Survival in this environment will depend on two factors: (1) avoiding detection and (2) high mobility and rapid repositioning. There are several gaps related to this situation:

- *Protection gap.* This scenario would see severe threats to American field artillery. The threat would include Russian ISR assets such as UASs equipped with various sensors, target-locating radars, and clandestine ground reconnaissance elements such as Spetsnaz (Russian special forces) teams. These reconnaissance and target acquisition systems are capable of finding American artillery units, and the Russian fire control system has the ability to quickly assign fire missions to cannon or rocket units. In addition to hostile artillery counterfire, a fight in the Baltics would include the Russian use of both attack helicopters and fixed-wing strike aircraft. In some circumstances, American field artillery units could be threatened by enemy ground maneuver units that broke through the front lines. U.S. field artillery units would have to employ appropriate tactics to reduce the severity of these threats. Frequent moves by firing elements (whether cannon or MLRS/HIMARS) will be necessary given the Russian target locating capabilities. Passive measures, such as use of camouflage and decoys (either electronic emitter or physical decoys to represent phony gun locations, for example), could improve survivability. The Russian UAS, helicopter, and fixed-wing aircraft threats will probably require field artillery units receive protection from U.S. air defense units.
- *Information gap.* The Army conduct tests to determine the overall signature of its various units and command posts and their vulnerability to geolocation and identification due to those signatures. Signatures in this sense include full-spectrum signatures: RF emissions, IR emissions, and EO signature. Such testing is essential to determining the precise capability gaps that need to be addressed with material solutions and to understand what opportunities there may be for TTP workarounds.
- *Capability gap.* Resolving the information gap is expected to lead to specific capability gaps in controlling the signature of Army units. Pending completion of such testing, we cannot identify specific gaps at this time.
- *TTP gap.* Over the past 15 years, Army units have faced adversaries that could not significantly exploit Army signatures (especially

RF signatures) and therefore made free use of the RF spectrum (including free use of personal electronics). Such unlimited use of the RF spectrum is likely to prove deadly. TTPs are need for enforcing the appropriate levels of emission control, especially when today's soldiers are likely to carry personal electronics that can easily identify them uniquely and reveal their position. These TTPs should be informed by test data that identify the signatures that are most likely to be exploited by Russian forces.

- *TTP gap.* Over the past 15 years, Army units have operated mostly out of fixed FOBs and combat outposts. In a Baltic scenario, this will prove deadly. TTPs (informed by test-derived data on vulnerabilities and intelligence on the speed of the Russian observe-orient-decide-act loop) are needed to determine how to (1) distribute mission command functions and (2) frequently and rapidly reposition mission command elements for survivability. Duplicate command elements operating in "leap-frog" fashion (one operating while the other is repositioning) is one TTP that the Army has experimented with recently. Further experimentation and exercise is needed to develop the best TTPs for the Army to adopt and train to.
- *Training gap.* Army units need to train in an environment in which the use of a radio—including soldier personal electronic devices—may prove deadly. This Army is just beginning to include emission control in their training. This needs to become a standard element throughout the training pipeline and reflect the latest information on signature vulnerabilities and the most up-to-date TTPs.

  A second part of the training gap is that the Army must regularly train to disperse its command post functions and frequently and rapidly reposition them. This is starting to happen, but must become a standard element of Army training and exercises.

Organization and Structure of U.S. Army Fires

In view of the significant overmatch by Russian fires, it will be essential to both maintain Army fires units in a dispersed formation while also being able to deliver concentrated fires when needed. Current Army organizational structure has the majority of fires units subordinated to the BCTs. While this is ideal for supporting fires, it is not automatically conducive to massing fires and supporting higher-level fires missions such as SEAD, counterfire, and deep interdiction. The reestablishment of Divisions Artillery (DIVARTYs) is a useful step in addressing fires missions at levels above brigade, but it is unclear whether it fully addresses the need. Questions remain as to how mission command will be exercised when fires units embedded in BCTs are needed to achieve mass of fire for higher-level missions. The Army should conduct further wargames and exercises to inform TTPs and any additional organizational and/or structural changes that are needed to ensure that Army can exercise mission command of fires to seamlessly support division, corps, and even joint fires missions while also providing necessary support to brigade and below. This is a capability that was not needed over the past 15 years, but must now be recreated to deal with the challenges of a Baltic scenario.

North Korean Scenarios

Due to lack of significant North Korean EW capabilities and expected rapid achievement of airspace supremacy, mission command challenges for the Army are focused primarily on two issues: interoperability with South Korea, and Army organization and structure to enable effective massing of fires. While a degree of interoperability with the South Korean Army is essential, the general concept of operations is for South Korean and U.S. forces to operate in separate sectors, with appropriate coordination between them but not close integration. In light of this, current TTPs and mechanisms developed by U.S. Forces Korea for such coordination are generally satisfactory, and it is our understanding that plans for future increments of CPOF, AFATDS, and TAIS meet the projected needs of U.S. Forces Korea.

The various scenarios for a North Korean war will require flexible use of both massed fires at levels above brigade and fires in support of brigade and below. Therefore, the same gap Army organization and structure gap identified for the Baltics applies here: The Army should conduct further wargames and exercises to inform TTPs and any additional organizational and/or structural changes that are needed to ensure that Army can exercise mission command of fires to seamlessly support division, corps, and even joint fires missions while also providing necessary support to brigade and below.

Iran Scenarios

The Iran scenarios call for limited, precision strikes by Army long-range fires (GMLRS, ATACMS, and their successors) based on primarily joint and/or national targeting data. Furthermore, fires missions assigned to the Army will originate from the joint targeting process (both deliberate and dynamic) that will almost certainly be centralized at the CAOC. The relatively low volume of Army fires (compared with the Baltics) means that joint data exchange will be easier, and TTP workarounds for direct digital exchange will generally be viable. Similarly, the low volume of Army fires will simplify airspace deconfliction. Dynamic targets may stress these capabilities and TTPs, but training and exercise should suffice to work out issues that may arise. Therefore, the important gap for Iran scenarios is in joint training: existing TTPs and processes for both joint deliberate fires by Army units and joint dynamic fires by Army units must be trained to, exercised, and (if needed) refined. To the best of our knowledge, such training and exercises are not occurring on a systematic basis. U.S. Army Central is best positioned (with support from FCOE and others) to take the lead on developing appropriate exercises.

Iraq/ISIL Scenarios

The mission command challenge in Iraq/ISIL scenarios is one of coordination with coalition forces in theater. The key challenge in this scenario is the deconfliction of fires so as to not unintentionally strike coalition partners. It is unclear to us whether a material solution is necessary or not. It is more likely that TTP solutions can address this problem, so we see this primarily as a TTP gap: the lack of TTPs for deconflicting fires with coalition partners. Again, U.S. Army Central is best positioned (with support from the Army Fires Center of Excellence and others) to address this gap by proposing appropriate TTPs and then training and exercising to these TTPs.

China/Pacific Scenarios

These scenarios again stress the joint challenges of mission command. As in the Baltics scenarios, the China/Pacific scenarios reveal gaps in the ability of the Army to receive targeting information from joint sources (in this case, primarily from the Maritime Component Commander) and to deconflict fires with joint partners (again, in this case primarily with the Maritime Component Commander, but for GMLRS and ATACMS, also airspace deconfliction with the Air Component Commander). The Army already has institutional and procedural relationships with the Air Component Commander (e.g., the Battlefield Coordination Detachment). However, it does not have such relationships with the Maritime Component Commander nor any TTPs for exchanging maritime targeting data or deconflicting fires. Developing such organizational relationship and TTPs with the Maritime Component Commander for exchanging targeting information and deconflicting fires—and then training and exercising to those TTPs—is the key gap in this scenario. The process of developing TTPs may reveal material gaps, such as a potential need to modify AFATDS, CPOF, and/or DCGS-A to receive, process, and display maritime data.

Strike

In this section, we explore capability gaps associated with Army weapon systems that deliver fires: the gun, rocket, and missiles systems; the warheads and munitions; the vehicles that carry those weapon systems; and the TTPs associated with operating these weapon systems. As in the case of Sense and Decide, the Baltics present the most stressful scenario.

Baltic Scenario

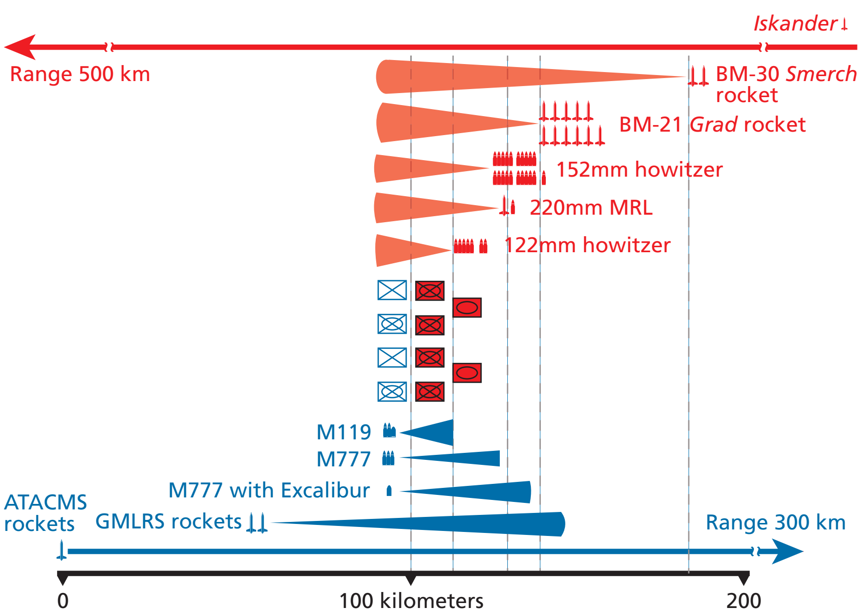
From the previous chapters, it is clear that there are three challenges for Army fires in a Baltic scenario:

- Range: Do Army fires have sufficient range to deal with Russian targets, including Russian long-range missile and rocket systems?

- Volume/mass of fire: Does the Army have sufficient capability and capacity to deal with the large number of Russian fires?
- Munitions/warheads: Does the Army have the right warheads for the kinds of targets and the environment of a Baltic scenario?

We begin by examining a synopsis of fires in a Baltic scenario. The balance of fires in the Baltics is represented in Figure 7.2. The center of the figure represents the notional line of contact between U.S. and Russian forces in a Baltic scenario. Russian fires that can range U.S. forces are shown on the top and right, illustrating the positions from which they can range U.S. forces. Along the bottom and left are illustrated the corresponding dispositions of U.S. Army fires and their abilities to range their Russian counterparts. The numbers of icons associated with each fire system indicate the approximate number of

Figure 7.2
Representation of Baltic Scenario Line of Contact and Corresponding Russian and U.S. Fires Systems



RAND *RR2124-7.2*

launchers of each kind (in a case assuming no predeployment or prepositioning of additional Army artillery units).

Figure 7.2 highlights several important points:

- *Iskander* cannot be ranged by Army fires unless the firing *Iskander* unit is unexpectedly close to U.S. forces.
- *Smerch* (BM-30) can be ranged by ATACMS or GMLRS—if GMLRS is brought sufficiently forward in the battlespace.
- There are relatively few *Iskander* and *Smerch* systems; the overwhelming majority of the fires systems that will range U.S. forces are the *Grad* (BM-21) rocket systems and Russian 2S19 MSTA 152mm howitzers.
- GMLRS can range the *Grad* (BM-21), but outnumbered by a factor of over five *Grad* launchers for every GMLRS launcher.
- M777 can range the Russian 2S19 MSTA howitzers (and *Uragan* rocket systems), but are outnumbered by a factor of about seven Russian 2S19 MSTAs for each U.S. M777.
- The M119 can just barely range the Russian D-50 122mm howitzers, but again are outnumbered by a factor of about three D-50s for every M119.

The implications of this are important to the Army. A lot of attention has been focused on how Russian fire systems outrange U.S. Army systems. However, there are relatively few Russian long-range systems. While these systems pose risks to important Army activities in the rear areas (aerial and sea points of disembarkation, command posts, airfields, etc.), the primary risk to Army combat units—and what will cause the vast majority of Army casualties—are the overwhelming number of shorter-range Russian fires systems (*Grad* rocket systems, and 152mm and 122mm gun systems). Existing Army system can already range these Russian systems, but U.S. fires systems are grossly outnumbered. This leads us to the following conclusion: The primary capability gap is not range, but rather weight of fire. The Army should prioritize increasing the numbers and firepower of its fires systems that can range Russian 122mm and 152mm gun systems and *Grad* rocket systems. This would require U.S. systems that can range about 25 km, 40 km, 50 km, respectively—ranges that are well within the capabilities of 155mm howitzers (M-777 and M-109A7) and GMLRS. Increasing the numbers and enhancing the lethality of cannons and GMLRS-like systems should be the Army priority for fires systems—this should be a much higher priority than increasing the range of Army fires. Furthermore, because this should not require new technology or increases in the size of rockets, launcher tubes, or gun rounds, this should be relatively affordable for the Army to do, compared with developing new, significantly longer-range guns and/or rockets.

It is important to highlight that the joint force cannot be relied on to assist the Army in dealing with the mid-range Russian fires systems. Early in a conflict with the Russians, airpower will not be available in significant numbers to support ground forces due to the formidable Russian IADS. What limited airpower is available to strike ground targets will be focused on the joint commander's highest priorities; it is unlikely that—outside exceptional circumstances—*Grad* launchers and Russian artillery pieces will rise to being priority targets. Even under the exceptionally optimistic assumption that airpower can destroy 50 percent of these Russian fire systems, U.S. Army fires will still be outnumbered by a factor of 2-to-1 or more. It falls primarily upon the Army to destroy the Russian mid-range fires capabilities—and the consequences (casualties) for failing to engage these systems also falls primarily on the Army.

If the Army prioritizes investments in addressing the capacity gap, how will it deal with the long-range Russian systems, specifically *Iskander* and perhaps future longer-range variants of *Smerch*? *Smerch*, even if it were to triple its range, will still be within range of ATACMS, so the answer for *Smerch* is for the Army to increase the number of ATACMS-like systems—again, the priority is to invest in increasing the numbers of ATACMS, not to invest to significantly raise the range of ATACMS. *Iskander*, however, will remain well out of range of any Army fires system. One option is for the Army to undertake development of a 500-km missile or rocket system, which would be an expensive investment. The Army's return on investment on this effort would be questionable, given the relatively small number of *Iskander* systems. It should also be noted that if an ATACMS replacement is roughly the same size as current missile, any increase in range beyond the current 300 km would mean that the payload of the weapon would suffer in order to extend the range.

There are a variety of Air Force and Navy long-range systems and air-launched systems, either in existence or under development, that can range *Iskander*—TACTOM, SDB I and SDB II delivered by fifth-generation aircraft, JSOW-ER)—and all of these are projected to be available in substantial numbers. Given the range of targets that *Iskander* can range in rear-areas (cities, aerial and sea points of disembarkation, headquarters of all kinds, airfields, Patriot sites, etc.), *Iskander* batteries should be treated as high-value targets for the joint force, in the same category with similar strike priority as strategic SAM systems. While the Army should continue research and development and S&T efforts to develop longer-range fires systems, the priority investment for the Army should be increasing the numbers and lethality of its mid-range systems, both cannons and rocket launchers. Joint systems are available to deal with the limited numbers of *Iskander* systems the Russians are projected to field.[4]

Finally, it is also important to point out that high-value Russian weapon systems such as strategic SAMs, *Iskander, Smerch*, and even *Grad* are expected to be protected by highly capable short-range and terminal air defense systems. The Army needs to research and conduct tests to determine whether its current and future munitions will reliably survive to the target and/or the TTPs needed to overwhelm such systems to ensure the target is struck. Understanding the survivability of Army munitions is a critical information gap in a Baltics scenario that the Army must address.

While this discussion was mostly focused on weapon systems, it is also important to note that the vehicles that carry GMLRS and

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[4] If the Russians deploy *Iskander* systems to Kaliningrad, these can be ranged by ATACMS and GMLRS systems appropriately located in Lithuania and/or Poland. *Iskander* systems deployed deeper in Belorussia or Russia would potentially be out of range of ATACMSs located in the Baltic states—joint capabilities would be required to strike *Iskander* systems in these locations.

ATACMS systems are due to reach end of life around 2035.[5] Our understanding is that a replacement vehicle has not yet been identified nor a SLEP planned. The Army needs to either program and budget a replacement vehicle or a SLEP of existing vehicles to prevent a critical capability gap in the out-years.

North Korean Scenarios

The North Korean scenarios present two key gaps for U.S. Army fires. The first gap is that the Army today does not have a penetrating munition suitable for reliably engaging hardened targets, such as reinforced artillery firing positions in the Kaesong Heights. The second gap is the sufficient fires: As described in Chapter Two, there are potentially nearly 20,000 tanks, armored vehicles, artillery pieces, and rocket launchers that need to be engaged. Unlike the Baltic scenario, airpower can be expected to destroy a large number of these. But even if airpower can destroy 500 per day (exceptionally optimistic), there will still be thousands to be engaged by Army fires—with only nine South Korean and two U.S. artillery brigades.

Iran Scenarios

Existing weapon systems and munitions adequately meet the needs of Iran scenarios. Because of collateral damage concerns, precision munitions will be preferred, but the limited number of targets suggests that existing inventories will be sufficient. In terms of cannons and rocket launchers in an Iran scenario, the capability of the systems the Army has or is planning on fielding appear adequate.

Because of the need to support the other services, primarily the Navy and Air Force, in suppressing Iranian air defenses and also to engage mobile Iranian coastal defense missiles firing from the north side of the Straits of Hormuz, the Army needs to maintain an ATACMS-like capability.

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5 Input provided by the Fire Support Capability Area team, U.S. Army Aviation and Missile Research Development, Huntsville, Alabama, April 2016.

Iraq/ISIL Scenarios

Existing weapon systems and munitions adequately meet the needs of Iran scenarios. Due to collateral damage concerns, precision munitions will be preferred, but the limited number of targets suggests that existing inventories will be sufficient. There are no significant weapon system related capability gaps in an Iraq scenario.

China/Pacific Scenarios

China/Pacific scenarios require two fires capabilities that the Army currently does not have. The first is a much longer-range fire system than any the Army currently fields. The Army would require an MRBM or GLCM with a range of approximately 1,200 km to be able to range eastern China from South Korea, Japan/Okinawa, or the Philippines. Such a system would also have to be designed to survive Chinese IADS (a challenge particularly for a GLCM, but potentially also for an MRBM). And to have a significant military effect, the Army would require large numbers of such systems. This would be a very significant cost for the Army at a time when modernization budgets are constrained. Furthermore, in view of existing systems and already programmed investments by other services for weapons that can strike the Chinese mainland, it is dubious that this would be an effective return on investment for the Army or the joint force, especially in view of other, more-fundamental Army capability gaps identified for the Baltic scenario.

The second fires capability called for in the China/Pacific scenario is an anti-ship capability. To the extent that existing Army systems (M777, GMLRS, ATACMS) can be used to strike ships (and to the extent that TTPs are in place and practiced for conducting such fires in support of the Maritime Component Commander), this is potentially a low-cost investment. However, if a dedicated anti-ship weapon has to be developed, it is not clear that the return on investment to the Army and joint force would be worthwhile. The joint force already has plenty of fires capability against maritime targets. We are skeptical of the value of such investments, in view of the compelling gaps in Army capabilities for a Baltics scenario. These capabilities are likely to be very expensive for the Army to address, yet add little net capability to what already exists in the joint force.

This chapter has highlighted fire-related capability gaps. The nature and severity of these gaps varies depending on the scenario. The challenges that Army field artillery would encounter in the Baltics are not the same as a fight against ISIS. The final chapter of this report will offer specific recommendations that the Army should consider in order to improve its field artillery.

Summary

This chapter has summarized current field artillery capability gaps in the areas of Sense, Decide, and Strike. Depending on the scenario, gaps in these areas could have serious consequences for the field artillery and the entire U.S. force.

The gaps are most noticeable in the Baltics scenario, where the United States would be opposed by a highly capable Russian force. In that situation, American ability to find targets and strike them in a timely manner would be degraded due to the limitations the Russians can impose on U.S. target acquisition systems. Additionally, U.S. field artillery assets would be exposed to attack by enemy indirect fires, attack helicopters, and fixed-wing aircraft.

Although the enemy would be less sophisticated in the Korean scenario, important capability gaps for the U.S. force would still exist in terms of the ability to engage large numbers of concealed enemy weapons, particularly the large numbers of artillery pieces the North Koreans would employ from fortified positions. In that case the field artillery's lack of munitions capable of penetrating well-constructed underground positions would be a significant limitation.

The final chapter of this report provides a number of recommendations to address the gaps noted in this chapter and other possible actions to improve overall U.S. field artillery capabilities.

CHAPTER EIGHT

Recommendations

This study examined the current state of U.S. Army field artillery, the types of operations that the service might be expected to conduct in the coming years, and the implications of those missions for the artillery. Because the Army will always fight as part of a joint force, the fires capabilities of the other services were included in the assessment. Additionally, the implications of various types of threats were also part of the analysis.

This final chapter makes a number of recommendations to improve the Army's field artillery. By their nature, most of these recommendations will require additional resources. At the time this report was prepared, the Army's budget was under considerable pressure—any decision for a new capability or more force structure in any branch of the service will require trade-offs. That said, given the fact that the field artillery represents a particularly important capability during high-intensity combat, and the undeniable reality that in the past 15 years artillery force structure and equipment modernization has been the target of significant cuts means that the Army will have to pay special attention to improving this branch.

An important element of this research was to take into consideration what the other services are doing in terms of fires systems and the associated target acquisition and ISR. The news is generally good for the Army. The Air Force, Navy, and Marine Corps are all modernizing their fires capabilities in a variety of ways, all of which will benefit the Army. That said, depending on the specific opponent, the ability of the other services to deliver fires in the quantity and in a timely enough manner to meet the Army's needs will be challenged. The most obvious example is the hypothetical fight against the Russians in the Baltics. In that case, the Air Force, in particular, will face a very difficult fight against a large array of very advanced air defenses. It will take time and considerable effort for the U.S. Air Force and other NATO air forces to bring the IADS to a manageable level. Losses, perhaps significant losses, of aircraft will take place while that effort is under way. While the NATO air forces are engaged in degrading the enemy's air defenses, their ability to support the Army with CAS, interdiction, and SEAD will be diminished. In addition to the effect enemy IADS will have on the ability of the other services to deliver fires, it will reduce the effectiveness of the ISR systems of the joint force. This, of course, has a direct bearing on the kinds of organic fires capabilities and ISR that the Army will need to fight against a high-end opponent with extensive air defenses. For example, in this situation there is a need for a greater number of Army long-range strike systems.

Against other opponents, the Army can count on much more extensive and timely air support from the other elements of the joint force. The North Korean air defense system, for example, is decades behind that of the Russians, and the North Korean Air Force is equipped with mostly 1960s-era systems. The Iranians are modernizing their IADS, which includes some very capable systems such as the Russian SA-15 and S-300, but the Iranians have limited quantities of late-generation air defenses. Therefore, depending on the opponent, the Army will have a varying amount of fires and ISR from the other services. In high-end scenarios, this reality means that the Army needs the ability to fight with limited joint support, at least for a period of time.

What specific changes should the Army consider in order to improve its field artillery capability? The unfortunate reality is that most of these will require new materiel solutions, and that means more money devoted to the field artillery. This is a time of fiscal constraint for the services, but given the importance of the field artillery in high-intensity combat operations, we believe that these are the types of improvements that are required.

1. Increase the number of field artillery units that can deploy quickly to a crisis or that are located forward, where the fast arrival of U.S. forces is essential.

Should a fight in the Baltics take place, the Army would be heavily outnumbered in the initial phases of the conflict. Army field artillery would be at a particular disadvantage given the numbers of fires units (cannons and rocket launchers) that the Russians could employ. All of the Army's active duty cannon battalions are currently organic to the BCTs. Having a larger number of echelon-above-brigade field artillery units (cannon and MLRS/HIMARS) would improve the ability to resist possible Russian aggression. Increasing the number of rapidly deployable echelon-above-brigade field artillery units could be accomplished by some mix of a force structure increase for the active Army and/or changing the readiness status of some National Guard field artillery units to minimize the mobilization time required for them to deploy. Adding more active component field artillery units is the most expensive course of action, but it would result in the most deployable units. Changing the way some Guard field artillery units are managed in order to increase their availability for a short-notice crisis is a less expensive option, but would require some significant changes to the way some Guard artillery units are manned and trained.

In some theaters, the Army and DoD should consider deploying or prepositioning artillery equipment and ammunition forward so that they can enter a potential conflict in a timely manner. In the Baltics, North Korea, and Iran scenarios examined in this report, rapid response is essential to defending U.S. vital interests. Because of the mass of artillery equipment and ammunition, airlifting artillery to the theater may not be practical, and thus forward deployment or prepositioning may be the only way to get additional Army artillery into the conflict when it would be needed.

Until an increase in U.S. field artillery force structure is accomplished (a process that will require several years, depending on the amount of resources that are available to add new field artillery units), a partial solution could be to rely more on allied fires capabilities. Some U.S. allies (e.g., the ROK) have powerful, numerous artillery assets.

Allied capabilities should be integrated into U.S. fires planning to the maximum extent possible.

2. Improve Army counterfire ISR capabilities in numbers, range, and EW hardening.

The counterfire is mission specific to ground forces, in that air and naval forces do not have capabilities designed to detect the majority of ground-to-ground fires that concern the Army. Particularly in a Baltics scenario, the Army will face severe demands for counterfires against Russian artillery. For the foreseeable future, the TPQ-53 will be the Army's primary counterfire ISR capability. There are two areas of potential concern with that system: detection range and performance in the face of Russian EW. To ensure that it will have the counterfire capabilities it needs, the Army should extend the range of the TPQ-53 to counter the Russian *Smerch* rockets. It should ensure the TPQ-53's performance in the hard EW environments expected in a conflict with Russia. Finally, it should provide sufficient TPQ-53s to deployed units to make up for losses anticipated in a Baltics conflict.

3. Improve the Army's ability to quickly get and utilize ISR data from the other services.

Particularly in high-intensity combat against an opponent such as Russia, the Army's organic ISR systems will be threatened. Army UASs will be shot down or jammed, counterfire radars will be targeted by an opponent, and the ability of manned aircraft (e.g., helicopters) to conduct reconnaissance in enemy-controlled or contested airspace will be difficult or even impossible. Therefore, the Army, including the field artillery, may have to rely on joint ISR to a greater extent than is the norm today. For the Army to quickly take advantage of ISR data from joint systems, particularly new systems such as the F-35A Joint Strike Fighter, procedures—potentially developed in conjunction with the Air Force and Navy—must be in place and sufficiently exercised to enable that to happen. As the other services deploy new ISR systems, the Army should ensure it has the ability to receive data that these systems will generate.[1]

4. Modernize the Army's cannon systems, particularly in terms of range and rate of fire.

Although the Paladin Integrated Management program made a significant improvement to the Paladin's mobility, the system still lags considerably behind modern self-propelled howitzers in terms of its range and rate of fire. The Extended Range Cannon Artillery program has the potential to significantly improve both key attributes of the Paladin system. Rocket launchers such as MLRS and HIMARS are very important field artillery systems, but cannons are more appropriate for providing timely and continuous support to troops in contact. While range and rate of fire are important considerations for the Army's cannon systems, improvements should also include lethality, system survivability, and mobility. For example, the cannon system employed in the Army's SBCTs is the M777 155mm, a towed system that lacks an auto-loading capability and protection for the gun crews.

5. Ensure there is a timely and adequate replacement for ATACMS.

The inventory of ATACMS missiles is declining rapidly. Given the possibility that the Army will have to fight, at least initially, under conditions in which the joint force does not have air superiority, a long-range surface-to-surface strike system is a very important capability. Ensuring that there is an ATACMS-like capability—like the PrSM under development—in the field artillery also has important implications for the other services. In the case of the Baltics, the Air Force and Navy will face a very severe air defense environment. A long-range Army strike capability that can contribute to the joint SEAD effort would be of considerable benefit to the other services.

[1] In addition to developing procedures to use joint ISR data quickly, the Army should maintain the ability to use its own data quickly. That would enable the Army to attack fleeting targets important in certain scenarios, such as long-ranged North Korean artillery and North Korean WMD systems.

Related to ATACMS replacement, the system currently lacks a penetrating warhead for attacking targets such as the fortified artillery emplacements near the DMZ in North Korea. Developing such a warhead would enable ATACMS to contribute to allied efforts to neutralize enemy artillery in the event of a North Korea conflict and successfully attack hardened targets in other scenarios where they may be present.

Finally, in scenarios where U.S. forces may face the most modern air and missile defenses, such as the Baltics, Army munitions could potentially be vulnerable to interception/destruction by short-range and terminal air defense systems. To ensure that an ATACMS replacement remains capable in those scenarios, the Army should seek to understand the survivability of its munitions and take steps to improve it where necessary.

6. Improve Army ground forces target acquisition capabilities.

Particularly in a Baltics conflict, the Army is likely to face heavy enemy use of obscurants, jammers, and/or blinding systems to prevent Army forces in contact from acquiring targets for Army artillery. To minimize the effectiveness of those efforts, the Army should test its current and future target acquisition systems against anticipated adversary countermeasures.

7. Improve the Army artillery's ability to provide fire support to allied and coalition partners.

Most future Army operations are envisioned as taking place with allies or partners. As allied and partner ISR and mission command capabilities lag U.S. capabilities, they will rely on the United States for targeting, deconfliction, and mission command for allied fires provided to support U.S. forces (e.g., in Europe or Korea) and for U.S. fires provided to support allied and partner forces. Allowing such mutual support will require that Army mission command systems (such as CPOF, AFATDS, and TAIS) interoperate with allied systems or that the Army extend its capabilities to allies and partners. Interoperation will require accommodations by both U.S. and allied/partner national systems with respect coordinating communications and data exchange systems and protocols. It will require training together in their use. Extending Army capabilities to allies and partners will require the provision of Army target acquisition and communications capabilities to them by providing Army fires liaison teams with the appropriate equipment to operate with their maneuver elements. It will also require coordinating with allies and partners and training together for their employment. Because supporting allies and partners is envisioned to be an important aspect of potential future operations, the Army (and DoD) should make the necessary provisions for doing so.

8. Enhance the field artillery's EW and cyber resilience.

The Army may face sophisticated EW and cyber attacks, particularly in a Baltics scenario, that could degrade Army command, control, and communications, and thus break Army artillery kill chains. To provide resistance against such attacks, the Army should test its communications and information systems (including PNT-related systems) in realistic EW and cyber conditions. It should create or re-create TTPs for how it will fight in a communications- and/or PNT-denied environment. It should also train in an environment in which the information it has become used to having is no longer available.

Given the need for field artillery units to communicate with all the elements of Army combined arms formations, the need to protect all platforms and databases from cyber attack will be critical, especially when fighting opponents with considerable offensive cyber capabilities. The guidance systems of older precision weapons, as well as field artillery C2 systems, may be especially vulnerable to EW and cyber attacks.

9. Reduce the artillery's vulnerability to EW-targeted fires

Russian forces can geolocate RF emissions and rapidly launch fires barrages at their locations. To survive in the face of such a threat, Army artillery units will have to avoid detection and employ rapid repositioning to avoid attack. To enable this, the Army should conduct tests to determine the RF, IR, and EO signatures of its units and command posts and their vulnerability to geolocation and identification. It should develop and train with TTPs to enforce the appropriate levels of emission control needed for self-protection. It should also develop and train with TTPs for distributing mission command functions and frequently and rapidly repositioning mission command elements for survivability.

10. Improve the survivability of artillery units.

When fighting an opponent such as the Russians, American field artillery units will face multiple threats from indirect fires, attack helicopters, armed UASs, and fixed-wing aircraft. In some cases, the artillery could be engaged by enemy ground maneuver units that would include armored vehicles. U.S. artillery units should train for this type of operational environment using appropriate active and passive techniques to reduce the threats they will face. In some cases, field artillery will be dependent on the capabilities (e.g., air defense) of other branches.

11. Emphasize major opponents in field artillery, combined arms, and joint training exercises.

The past 15 years of combat operations had a major impact on the readiness and even the culture of Army field artillery. Mid-grade and junior leaders came to think of employing fires in a COIN environment. "Massing fires" for many of these artillery soldiers meant bringing a handful of cannons to bear on a target, as opposed to earlier concepts of massed fires in which dozens or even hundreds of weapons would simultaneously engage a target. Today, few field artillery units have camouflage systems to conceal their weapons—this equipment was turned in during 2008–2009 because it was deemed unnecessary in Iraq and Afghanistan. Against a powerful opponent such as Russia, cover, concealment, and deception will be essential. Field artillery units must train that way.

12. Examine foreign systems for possible U.S. field artillery use.

There may be a number of foreign fires systems that could be applicable for possible U.S. use, including howitzers, such as Germany's PzH2000 155mm self-propelled cannon.

13. Continually assess technology trends that could improve the effectiveness of field artillery units.

The focus of this study was the period from today to 2025–2030. That means that any new field artillery–related system deployed in that time frame would have to already be fairly well developed. This reality limits the Army's options for new systems between now and 2030. That said, the field artillery should continually examine technology options that could, in the mid-to-far term, improve its capability, including the possible use of foreign systems, as was mentioned in the previous recommendation.

APPENDIX

Army Indirect Fires in an Operational Context: A Historical Analysis (1985–2003) with a View Toward the Baltics (2020)

Introduction

In this appendix, we carry out an analysis of U.S. Army indirect fires in an operational context, charting the historical evolution of fires capabilities and projecting ahead for future Army missions. Our historical analysis covers a period of approximately two decades, extending from the end stages of the Cold War through the second Iraq War. It focuses on three case studies: NATO's Central Front (1985–1989), Operation Desert Storm (1991), and OIF (2003). It provides a quantitative assessment of Army fires capabilities, focusing on three types of battlefield missions: direct support, counterfire, and deep strike. The historical analysis also provides the backdrop for a comparative analysis of the projected capabilities in future conflicts, focusing on a Baltic scenario in 2020 as an illustrative case study.

Several factors influence the effectiveness of indirect fires in the battlefield: (1) the quantity of weapon systems, (2) their technical sophistication and specifications, and (3) a force structure allowing for the effective utilization of the available resources.

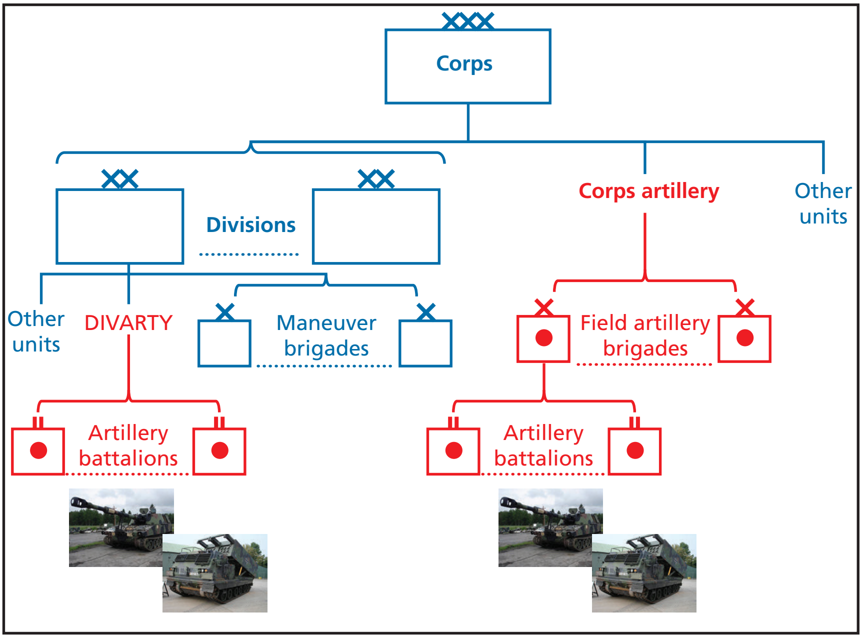
We have not attempted to explicitly analyze the influence of force structure in this study, choosing instead to focus on the quantity and specifications of the weapons in analyzing the operational capabilities of Army indirect fires. Nonetheless, we will begin by presenting a high-level overview of the organization of combat units, highlighting in particular artillery units and their roles within the larger combat units. We will then proceed with our case studies and, finally, our analysis and conclusions.

Organization of Combat Units

1985–1991

The structural organization of combat units during the 1985–1991 period was substantially similar in the first two case studies considered (Figure A.1). A corps consisted of two or three divisions, corps artillery, and various other units. The corps artillery consisted of two or three field artillery brigades, each fielding several specialized battalions. Each division consisted of three maneuver brigades, a DIVARTY in which

Figure A.1
Organization of U.S. Army Corps (1985–1991)



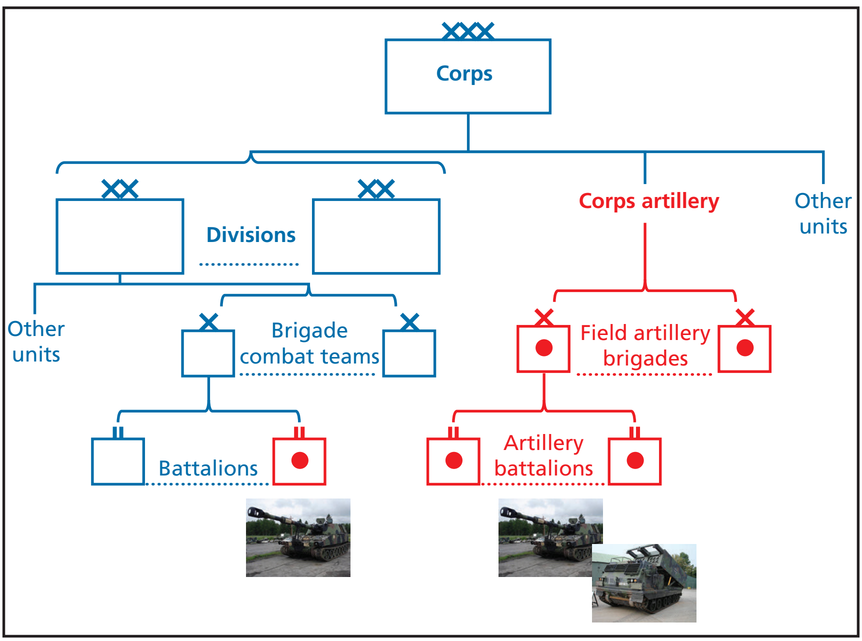
RAND *RR2124-A.1*

all the artillery capabilities of the division resided, and various other units. As such, each division had its own organic artillery capabilities and could additionally be reinforced by field artillery brigades from the corps, with the DIVARTY tasked with calling for and coordinating all artillery fires across the division.

Transition to Modular Force Structure

During the early 2000s, the Army underwent structural changes as it evolved to better adapt to COIN operations. The Army's Modular Force restructuring was particularly evident at the division level, transforming the traditional maneuver brigades into BCTs with organic artillery capabilities (Figure A.2) and resulting in the deactivation of the DIVARTY. Moreover, 155mm cannon batteries were reduced from

Figure A.2
Organization of U.S. Army Corps Post Restructuring



RAND *RR2124-A.2*

eight to six guns, thus reducing cannon battalions to 18 guns across the board. As such, whereas the artillery capabilities of a division were previously concentrated within the DIVARTY, they were now thinned out and spread across the brigades, as was their command, rendering massed fire missions more challenging and arguably less effective.

NATO Central Front (1985–1989)

Context and Theater of Operations

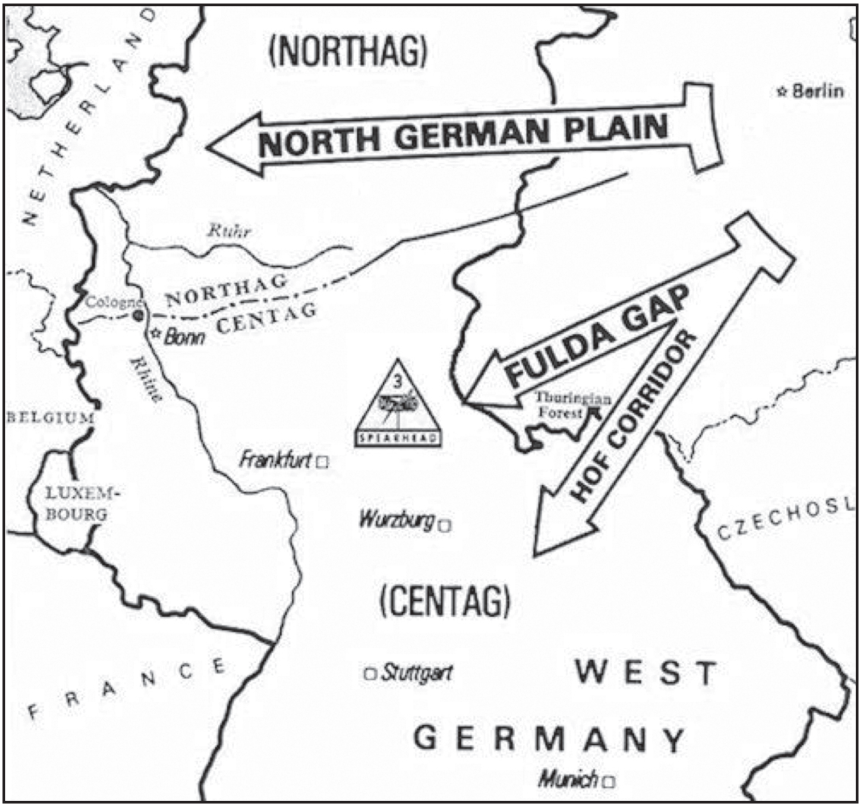
The North Atlantic Treaty was signed in Washington, D.C., on April 4, 1949, creating an alliance between the United States, Canada, and ten Western European countries to counter the expansionist threat posed by the Soviet Union after the Second World War. A Long-Term Defense Plan was subsequently developed for the defense of Western Europe against a potential Soviet invasion, focusing on forward defense of the Ijssel-Rhine line on NATO's Central Front (Figure A.3). Three land corridors cut across the Iron Curtain from the Warsaw Pact countries in the East into West Germany. Two of those, the Fulda Gap and the Hof Corridor, lay in the sector of operations of the Central Army Group (CENTAG), NATO's forward defense in the southern half of the Federal Republic of Germany. Two U.S. corps formed the center of the CENTAG. Their indirect fires capabilities in the period 1985–1989 are the subject of this case study.

Artillery Units and Role

The U.S. V Corps was deployed in the sector assigned to the defense of the Fulda Gap heading toward Frankfurt-am-Main, covering a front approximately 90 km in length (Figure A.4). The artillery capabilities of the corps resided within the DIVARTY of its two divisions (3rd Armored Division and 8th Mechanized Infantry Division) and within its two field artillery brigades (41st and 42nd).

The U.S. VII Corps was deployed in the sector assigned to the defense of the Hof Corridor heading toward Munich, covering a front approximately 150 km (Figure A.4). The artillery capabilities of the Corps resided within the DIVARTY of its two divisions (1st Armored

Figure A.3
NATO's Central Front

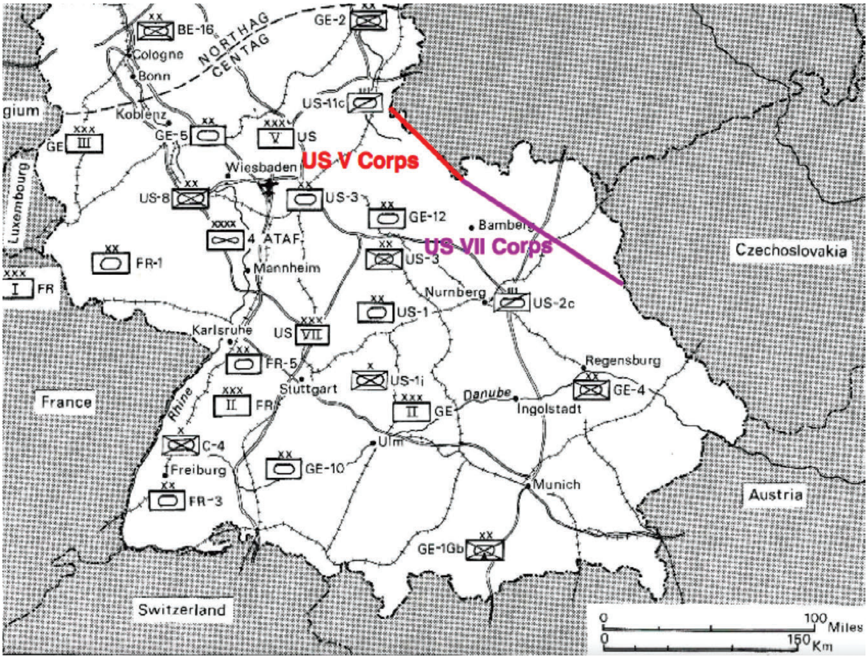


RAND *RR2124-A.3*

Division and 3rd Mechanized Infantry Division), its three field artillery brigades (17th, 72nd and 210th), and the 3rd Brigade (usually a subordinate unit of the 1st Infantry Division).

In a conventional warfare scenario, the Warsaw Pact countries were expected to launch a surprise multifront attack, organized in echelons per Soviet doctrine. NATO forces were thus expected to face multiple waves of heavily armored Soviet forces, rendering the transition from defense to counter-attack challenging. U.S. Army units defending the Central Front would follow the Army's AirLand Battle

Figure A.4
Operational Sectors of the U.S. V and VII Corps, NATO Central Front



SOURCE: Adapted from Isby and Kamps (1985).
RAND *RR2124-A.4*

doctrine, combining elements of active defense with maneuver warfare and deep battle concepts (Field Manual 100-5, 1986). Army units would counter-attack Soviet armor as they broke through the lines, limiting their penetration into NATO-held territory, while striking deep behind enemy lines targeting the second echelon of troops, thereby neutralizing the adversary's reinforcements. Medium to heavy artillery and precision-guided munitions used at standoff ranges were integral to this defense and counter-attack strategy.

Weapons and Their Specifications

Table A.1 details the indirect fire weapons of the U.S. V and VII Corps. In many instances, a range is indicated, because the makeup of the units and their weapons fluctuated over the years. The descriptions and

Table A.1
Artillery of the U.S. V and VII Corps, NATO Central Front (1985–1989)

		Equipment			
		M109A2/3	M110A2	M270	Lance
U.S. V Corps					
Division Artillery	Division Artillery, 3rd Armored Division	72	—	9	—
	Division Artillery, 8th Infantry Division (Mechanized)	72	—	9	—
Corps Artillery	41st Field Artillery Brigade*	24/48	48	0/27	6
	42nd Field Artillery Brigade*	—	48/72	—	12
Total[a]		168/192	96/120	18/45	18
U.S. VII Corps					
Division Artillery	Division Artillery, 1st Armored Division	72	—	9	—
	Division Artillery, 3rd Infantry Division (Mechanized)	72	—	9	—
Corps Artillery	17th Field Artillery Brigade*	24/0	48/72	—	6
	72nd Field Artillery Brigade*	—	72	0/27	6
	210th Field Artillery Brigade*	0/48	48/24	—	6
Other	3rd Brigade, 1st Infantry Division	24	—	—	—
Total[a]		192/216	168	18/45	18

SOURCES: Data compiled from Isby and Kamps (1985); Globalsecurity.org (undated); and Johnson and Callahan (2012).

[a] Two numbers are indicated in instances where cannon or rocket launcher numbers fluctuated over the period of time considered: The first and second numbers provided correspond to 1985 and 1989, respectively.

relevant technical specifications of these weapons are summarized in Table A.2. The Lance missiles were specialized systems with a nuclear role, fielded by several dedicated artillery battalions. As such, while we

Table A.2
Indirect Fire Weapons and Their Specifications, NATO Central Front (1985–1989)

Equipment	Description	Range	Rate of Fire
M109A2/3	155mm self-propelled medium howitzer	18 km/ 23.5 km with RAP	Max: 4 rounds/min Sustained: 1 round/min
M110A2	8″ self-propelled heavy howitzer	17 km/ 29km with RAP	Max: 1round/min Sustained: 1 round/2 mins
M270	MLRS (12 rockets)	40 km	Salvo duration: 48 secs Reload: 5–10 mins
Lance	MGM-52 Battlefield support missile (nuclear warhead)	120 km	—

SOURCES: Data compiled from Isby and Kamps (2005); Federation of American Scientists, Military Analysis Network (undated); Dugdale-Pointon (2008).

have included them here for completeness, we will not be taking them into account in our comparative analyses in later sections. Additionally, we have opted not to reference the Pershing II missiles that were deployed in 1985 and were subsequently dismantled following the INF Treaty in 1987.

Case Study: Operation Desert Storm (1991)

Context and Theater of Operations

On August 2, 1990, Iraq launched an offensive against neighboring Kuwait, with the Iraqi Army consolidating its invasion of Kuwait and deploying along the southern border with Saudi Arabia within 48 hours (Figure A.5). A series of UN Security Council resolutions were subsequently passed, culminating in Resolution 678 requiring Iraq to withdraw by January 15, 1991. An allied coalition of 34 nations was formed, led by the United States. On January 17, 1991 (Gulf time), Operation Desert Storm was launched with allied air strikes against Iraqi targets. On G-day, February 24, 1991 (Gulf time), a 100-hour ground offensive was launched over a front stretching 380 km from the Persian Gulf into the desert South of Iraq. Two U.S. corps carried out left flank mis-

Figure A.5
Kuwait Theater of Operations

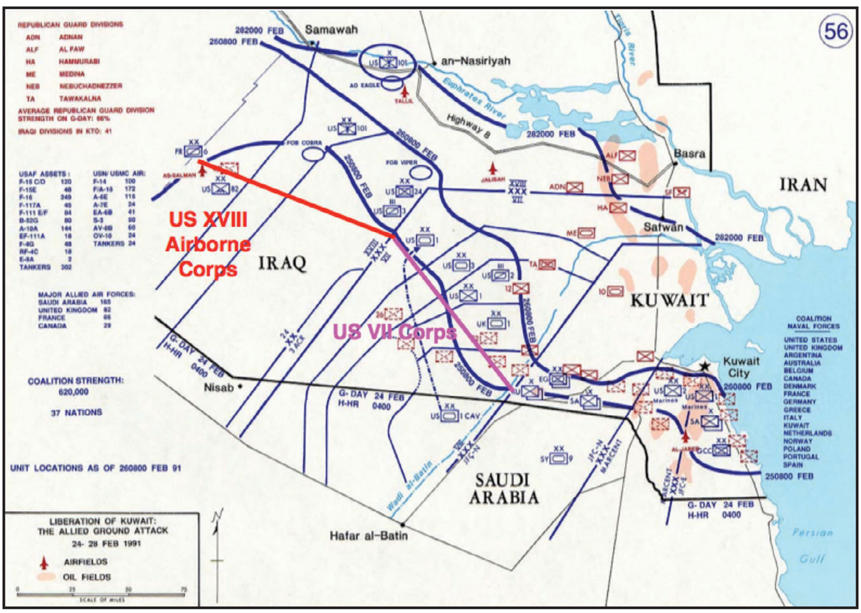
SOURCE: Stewart, 2010.
RAND *RR2124-A.5*

sions in Iraq, with the goal of sealing off and destroying Iraqi forces west of Kuwait, while two Marine Corps divisions crossed Kuwait's southern border, heading north toward Kuwait City. The indirect fire capability of the Army units partaking in Operation Desert Storm is the subject of this case study.

Artillery Units and Role

The U.S. XVIII Airborne Corps held the western flank of the ground offensive, attacking 260 km deep into Iraq reaching the Euphrates River and covering a rapidly moving front approximately 145 km (Figure A.6). The artillery capabilities of the Corps resided within the DIVARTY of its three divisions (82nd Airborne Division, 24th Mechanized Infantry Division, and 101st Airborne Division) and within its

Figure A.6
Operational Sectors of the U.S. XVIII Airborne and VII Corps, Operation Desert Storm



SOURCE: U.S. Military Academy Department of History.
RAND *RR2124-A.6*

three field artillery brigades (18th, 212th, and 196th). Additionally, the artillery capabilities of the 3rd Armored Cavalry Division that was assigned to the XVIII Corps are included in this analysis.

The U.S. VII Corps was deployed to the right of the XVIII Corps, moving north and then east in destroy the core of the Iraqi ground forces, covering a front approximately 135 km (Figure A.6). The artillery capabilities of the Corps resided within the DIVARTY of its three divisions (1st Armored Division, 3rd Armored Division, and 1st Mechanized Infantry Division) and within its three field artillery brigades (42nd, 75th, and 210th). Additionally, the 142nd National Guard Field Artillery Brigade was assigned to the VII Corps, and the 1st Armored Cavalry Division was released from theater reserve to control of the VII Corps on February 26. The artillery capabilities of both are included in the analysis.

Artillery roles and requirements were different in the pre-G-day operations versus the 100-hour ground offensive. Indeed, a firepower battle began pre-G-day with VII Corps artillery launching a series of raids near Wadi-Al-Batin followed by choreographed raids by groups of MLRS batteries, taking down the Iraqi guns within range of the Wadi while reinforcing the Iraqi belief that the main coalition attack would come up the Wadi, thereby contributing to the success of the deception plan. Combined artillery and attack helicopter raids were also carried out in preparation for the main offensive, with artillery fire used to saturate Iraqi air defenses. During the ground offensive, indirect fire missions were particularly challenging, due to the fast movement of the mechanized maneuver forces, crossing hundreds of kilometers of terrain within the span of 100 hours and requiring rapid fire and agility above all (Abrams, 2015).

It is worth noting that Army National Guard artillery played a significant role in this theater: Indeed, of the XVIII Corps assets, one out of two of the 155mm cannon battalions, and two out of three of the 8" cannon battalions were from the National Guard. Of the VII Corps assets, three out of the seven MLRS batteries and two out of the three 8" cannon battalions were from the National Guard.

Weapons and Their Specifications

Table A.3 summarizes the indirect fire weapons of the XVIII Airborne and VII Corps during the ground offensive. The descriptions and relevant technical specifications of the weapons are summarized in Table A.4. Operation Desert Storm saw the first use of the ATACMS in combat, whereby a total of 32 missiles were fired from M270 MLRSs. These are summarized in Table A.4 for completeness but not otherwise taken into account in our analysis (or listed in Table A.3). Air defense artillery, particularly the MIM-104 Patriot missiles, also played an important role. These are not covered in this report.

Operation Iraqi Freedom (2003)

Context and Theater of Operations

On March 19, 2003, an allied coalition of countries led by the United States launched an aerial bombing campaign against targets in Iraq. On March 20, 2003, a ground offensive was launched from Kuwait, with 21 days of major combat operations ensuing in Iraq. The U.S. V Corps and I Marine Expeditionary Force drove north in two columns (Figure A.7) toward Iraq's capital, Baghdad, capturing it on April 9, 2003. The artillery capabilities of the U.S. V Corps during the offensive is the subject of this case study.

Artillery Units and Return on Investment

The U.S. V Corps was tasked with driving north in a column heading from Kuwait to Baghdad, securing Talil Air Base, Najaf, and Karbala on the way, and approaching Baghdad through the desert from the west after crossing the Euphrates River. The artillery capabilities of the corps resided within the individual BCTs of each of its four divisions (3rd Mechanized Infantry Division, 101st Airborne Division, 82nd Airborne Division, and 4th Mechanized Infantry Division) and within its three field artillery brigades (17th, 41st, and 214th).

On the evening of March 19, 2003, the V Corps had 54 M109A6, 60 towed light howitzers, and 18 MLRSs ready for combat spread among the 3rd Mechanized Infantry and 101st Airborne Divisions

Table A.3
Artillery of the U.S. XVIII and VII Corps, Operation Desert Storm (1991)

		Equipment[a]				
		M102	M109A3	M198	M110A2	M270
U.S. XVIII Airborne Corps						
Division Artillery	Division Artillery, 82nd Airborne Division	54	—	—	—	—
	Division Artillery, 101st Airborne Division	54	—	—	—	—
	Division Artillery, 24th Infantry Division (Mechanized)	—	72	—	—	—
Corps Artillery	18th Field Artillery Brigade	—	24	72	—	27
	196th Field Artillery Brigade	—	—	—	36	—
	212th Field Artillery Brigade	—	24	—	18	27
Other	Division Artillery, 3rd Armored Cavalry Division	—	24	—	—	—
Total		108	144	72	54	54
U.S. VII Corps						
Division Artillery	Division Artillery, 1st Armored Division	—	72	—	—	—
	Division Artillery, 3rd Armored Division	—	72	—	—	—
	Division Artillery, 1st Infantry Division (Mechanized)	—	72	—	—	—
Corps Artillery	42nd Field Artillery Brigade	—	48	—	—	27
	75th Field Artillery Brigade	—	24	—	18	27
	210th Field Artillery Brigade	—	48	—	—	9
Other	142nd Field Artillery Brigade (National Guards)[b]	—	—	—	36	27
	Division Artillery, 1st Armored Cavalry Division	—	48	—	—	9
Total		0	384	0	54	99

SOURCES: Data compiled from Englehardt (1991), Globalsecurity.org (undated), Stewart (2010), Thompson (undated), Schubert and Kraus (2005), Abrams (2015).

[a] Totals are based on cannon battalions with 18 guns each for M110A2 and M102 battalions, 24 guns each for M109A3 and M198 battalions, and rocket battalions with 27 rocket launchers each.

[b] The 142nd field Artillery Brigade supported both the 1st Infantry Division (Mechanized) and the 1st UK Armored Division.

Table A.4
Indirect Fire Weapons and Their Specifications, Operation Desert Storm (1991)

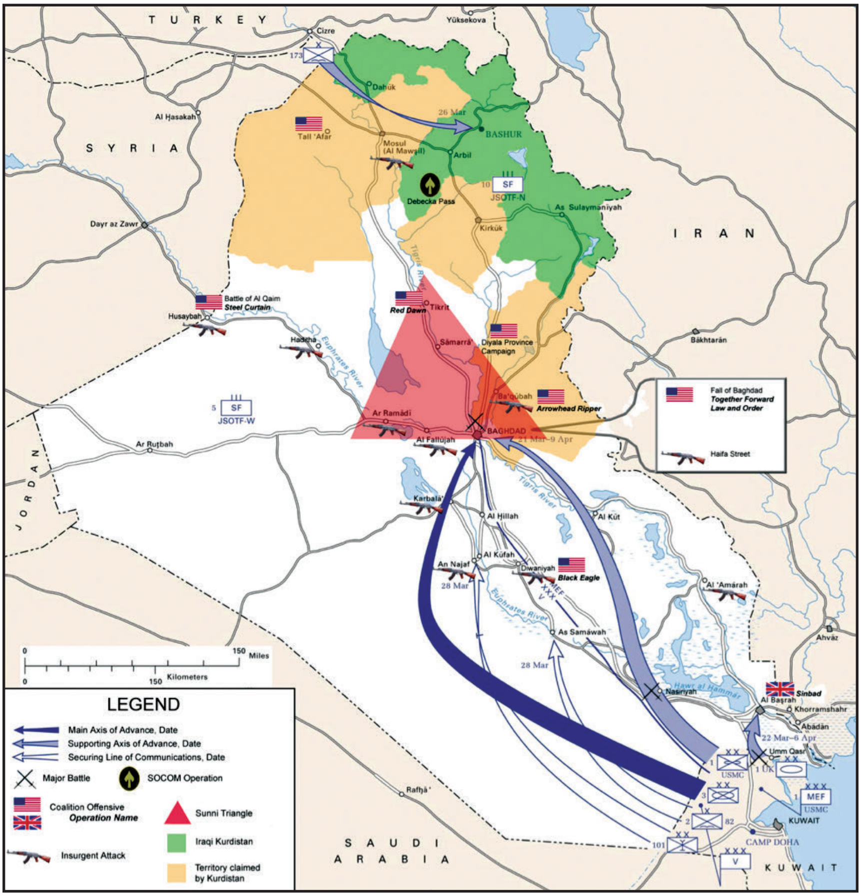
Equipment	Description	Range	Rate of Fire
M102	105mm towed light howitzer	11.5 km/ 15.1 km with RAP	Max: 10 rounds/min Sustained: 3 rounds/min
M109A3	155mm self-propelled medium howitzer	18 km/ 23.5 km with RAP	Max: 4 rounds/min Sustained: 1 round/min
M198	155mm towed medium howitzer	18 km/ 23.5 km with RAP	Max: 4 rounds/min Sustained: 1 round/min
M110A2	8" self-propelled heavy howitzer	17 km/ 29 km with RAP	Max: 1 round/min Sustained: 1 round/2 min
M270	MLRS (12 rockets)	40 km	Salvo duration: 48 sec Reload: 5-10min
ATACMS	MGM-140 Army Tactical Missile System (guided)	128 km	—

SOURCES: Data compiled from Schubert and Kraus (2005), Wikipedia (2017).

(Fontenot, Degen, and Tohn, 2005, p. 80). The 4th Mechanized Infantry Division was late in arriving to the scene, its original plans to advance toward Baghdad from the north having been blocked by the Turkish Parliament's refusal to grant landing permission on Turkish soil. It thus joined the fight as a follow-on force from Kuwait.

Artillery units played a strong supporting role in major combat operations by providing counterfire to destroy enemy cannon and rocket systems, thereby ensuring freedom of maneuver for their supported units. Integration of self-propelled artillery into maneuver formations allowed for timely and accurate fires. On the downside, the artillery-to-maneuver-forces ratios in this theater were the lowest they had been since the end of the 19th century ("U.S. Army Field Artillery Relevance on the Modern Battlefield," 2004). As such, units in this theater were sometimes in contact with the adversary without artillery direct support.

Figure A.7
Theater of Operations, Operation Iraqi Freedom



SOURCE: ADuran, 2007. Used with permission.

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Weapons and Their Specifications

Table A.5 summarizes the indirect fire weapons of the V Corps. Table A.6 summarizes the technical specifications of the weapons.

Table A.5
Artillery of the U.S. V Corps, Operation Iraqi Freedom (2003)

		Equipment		
		M109A6	**M-119A1**	**MLRS**
U.S. V Corps				
Brigade Combat Team Artillery	3rd Infantry Division (Mechanized)			
	1st brigade	18	—	—
	2nd brigade	18	—	—
	3rd brigade	18	—	—
	101st Airborne Division (Air Assault)			
	2nd brigade	—	18	—
	3rd brigade	—	18	—
	82nd Airborne Division			
	1st brigade	—	18	—
	2nd brigade	—	18	—
	4th Infantry Division (Mechanized)			
	1st brigade	18	—	—
	2nd brigade	18	—	—
	3rd brigade	18	—	—
Corps Artillery	17th Field Artillery Brigade	18	—	54
	41st Field Artillery Brigade	—	—	54
	214th Field Artillery Brigade	—	—	27
	Total	108	78	135

SOURCES: Data compiled from Fontenot, Degen, and Tohn (2005), Wikipedia (2017).

Table A.6
Indirect Fire Weapons and Their Specifications, Operation Iraqi Freedom (2003)

Equipment	Description	Range
M-109A6	Paladin 155mm self-propelled howitzer	24 km/30 km with RAP
M-119A1	105mm towed howitzer	14k m/19.5k m with RAP
MLRS	M270 MLRS (12 rockets)	40 km

SOURCE: Data compiled from Army Technology website (undated), Military.com (2017).

Quantitative Analysis

We use three metrics to quantify the indirect fires in an operational context:

- Metric 1 reports the total number of cannons.
- Metric 2 reports the number of cannons normalized by the length of the front (cannons/km).
- Metric 3 reports the total number of MLRS.

We have opted to provide the value of Metric 2 for the first two case studies only. For OIF, the invasion proceeded in columns with no clear front line, and was thus sufficiently different from the previous two case studies to render a meaningful direct comparison difficult for this particular metric. We carry out our analysis, presented in Table A.7, at the corps level.

We highlight the following points, evident from our analysis:

1. Cannon density is generally similar in the first two case studies considered, with Metric 2 ranging from 2.40 to 3.56 in value. Higher numbers in this range correspond to battlefields involving an armor heavy adversary. Indeed, on NATO's Central Front, cannons were more densely positioned in the Fulda Gap region covered by the V Corps, and considered to be one of two obvious routes of Soviet attack involving a major tank battle.

Table A.7
Metrics for Assessing Indirect Fires (Corps-Level Comparison)

	Metric 1 (# of cannons)	Metric 2 (cannons/km)	Metric 3 (# of MLRS)
NATO Central Front			
U.S. V Corps (1985)	264	2.93	18
U.S. VII Corps (1985)	360	2.40	18
U.S. V Corps (1989)	320	3.56	45
U.S. VII Corps (1989)	384	2.56	45
Operation Desert Storm			
U.S. XVIII Airborne Corps	348	2.40	54
U.S. VII Corps	438	3.24	99
Operation Desert Storm			
U.S. V Corps	186	—	135

SOURCE: Isby and Kamps, 1985.

During Operation Desert Storm, cannons were more densely massed with the U.S. VII Corps, tasked with engaging and destroying the armor-heavy, elite Iraqi Republican Guard units.

2. The use of MLRSs has markedly increased over the years. Indeed, while Metrics 1 and 2 are roughly comparable across the case studies, Metric 3 demonstrates a 2.5-fold increase in 1989, a 3–5.5-fold increase in 1991, and a 7.5-fold increase in 2003 compared with its value at the initial point of our study in 1985.

Comparative Analysis: The Baltics (2020)

Context

Following a prolonged period of thawing relations between Russia and its Western neighbors after the end of the Cold War, the recent Russian aggression against Ukraine coupled with escalating tensions and increasingly confrontational Russian posturing have reignited concerns about Russian expansionist aspirations in Europe. The Baltic states—Estonia, Latvia, and Lithuania—were admitted to NATO membership in 2004 and are a critical weak point on NATO's Eastern flank (Figure A.8). Defense of the Baltics is a thus a relevant scenario in planning for future Army fires. Moreover, the border separating the Baltic states from Russia and Belarus is similar in length and topography to that of NATO's Central Front, thus providing a natural basis for comparison to assess the evolution of the Army's indirect fire capabilities over time.

Projected Units and Weapons

RAND wargames have shown that, even with optimistic assumptions about the United States' ability to position troops in the Baltics, a division defending the Baltics will be expected to cover a front that is 120–150 km long (Shlapak and Johnson, 2016a). We assume for our analysis that a division consists of three BCTs, each with an organic cannon battalion of 18 guns, and is reinforced by one rocket battalion with 27 GMLRSs. The projected weapons and their specifications are shown in Table A.8.

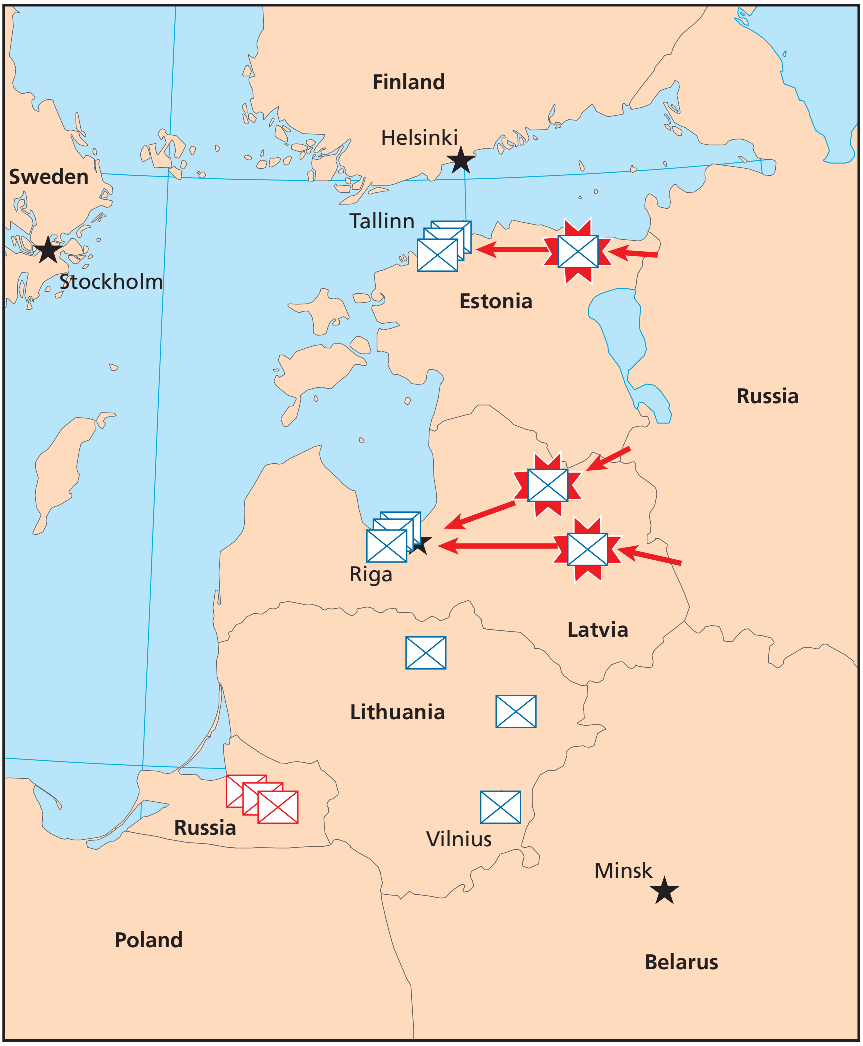
Comparative Analysis

Carrying out a comparison between Army indirect fires on NATO's Central Front and the scenario described above for the Baltics, we note that the value of Metric 2 in the Baltics scenario is only 1.35, which is strikingly lower than its value in any of the historical case studies considered, providing the first indication that the density of fire has been reduced significantly.

To account for weapon range in our analysis, we summarize the Army fires capabilities for NATO's Central Front and that projected for the Baltics in Figure A.9, employing the same scale for both graphs, thereby allowing for a simple visual comparison of the two scenarios. In our analysis:

1. We use the U.S. V Corps as the basis for comparison on NATO's Central Front. We assume that each division of the

Figure A.8
Theater of Operations, The Baltics



SOURCE: Shlapak and Johnson, 2016a.
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Table A.8
Projected Weapons for a Baltics Scenario (2020)

Equipment	Description	Range
M-109 Paladin/ Excalibur	Precision guided extended range M982 munitions launched from M109A6 Paladin 155mm self-propelled howitzer	40 km
GMLRS	Guided Multiple Launch Rocket System (6 rockets)	84 km

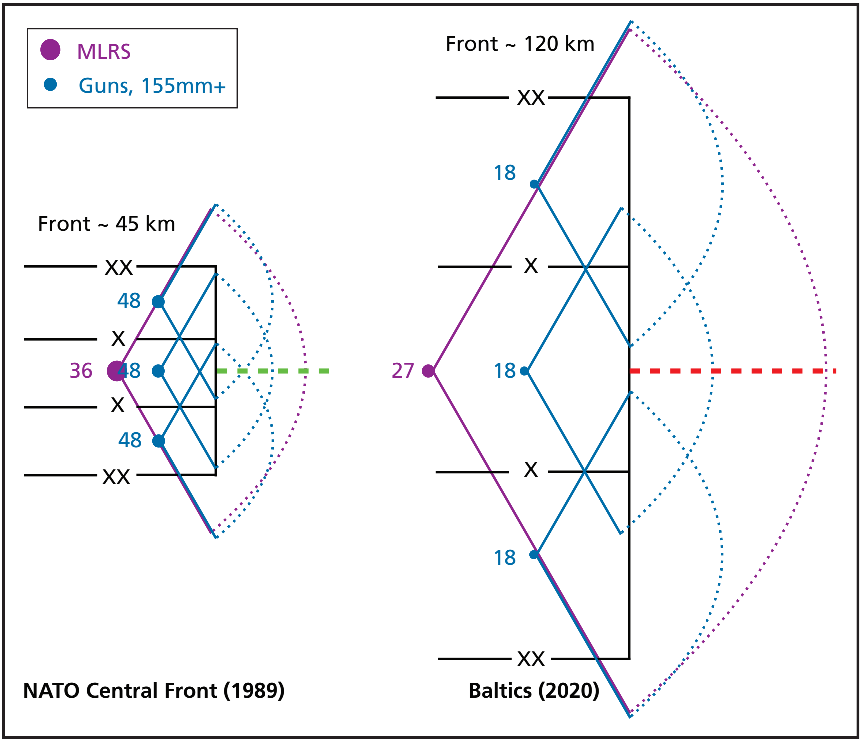
SOURCE: Data provided by the Field Artillery School.

U.S. V Corps was tasked with defending half the sector, or approximately 45 km of front. We further assume that a division was supplemented by one field artillery brigade, including an MLRS battalion, and three medium to heavy cannon battalions (M109A2/3 or M110A2). Finally, we use the range associated with the M109 guns for our analysis, painting a more conservative picture.

2. We assume that a division in the Baltics will be responsible for 120 km of front, a somewhat optimistic assumption.
3. In each scenario, we position all the artillery battalions for each brigade at the center of the brigade's front line and pushed back front the front by a distance equal to one half the maximum range of the cannons. We position all the MLRS batteries at the center of the division's front line and pushed back from the front by a distance equal to one half the rocket range. These are obviously simplifying assumptions, but they are good enough for an order-of-magnitude analysis, which is what we are striving for here.

As Figures A.9 and A.10 illustrate, while the range of the weapons has improved over the years, the density of fire has been significantly reduced, owing to the simultaneous drop in the number of weapons available to combat units and the increased frontage that the units are expected to cover.

Figure A.9
Army Fires in the Battlefield: NATO Central Front (1989) Versus Baltics (2020)



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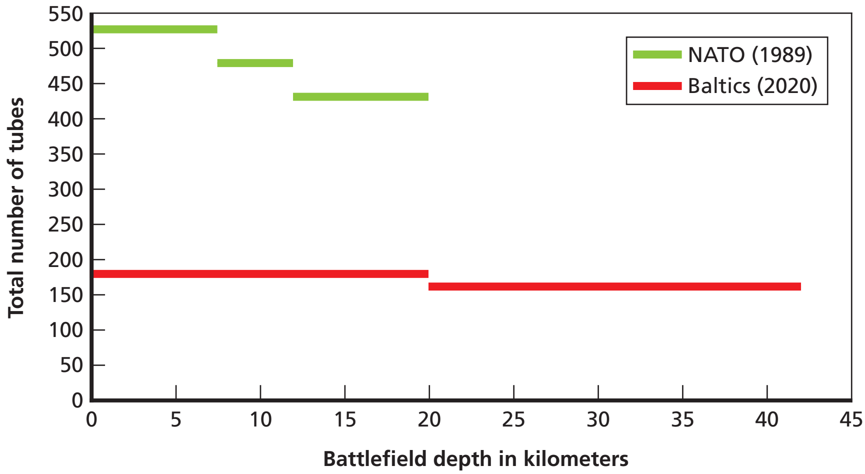
Conclusions

Army indirect fires have been characterized by two opposing trends: (1) an improvement in weapon technology, leading in particular to greater weapons range, and (2) a significant reduction in the number of weapons deployed in combat units due to restructuring. These trends have been coupled with a marked decrease in the overall number of combat units and an increased reliance on Army National Guard artillery units. As evidenced by the comparison drawn between our historical case study of NATO's Central Front and a potential scenario in the Baltics in 2020, the technical improvement of the weapons has not

Figure A.10
Army Fires in the Battlefield: Number of Artillery Tubes Plotted Against Battlefield Depth, NATO Central Front (1989) Versus Baltics (2020)



RAND *RR2124-A.10*

been sufficient to counterbalance the reductions in combat units and their indirect fire weapons. The net effect is a marked decrease in density of fire, with the potential to severely limit massed fire capabilities, thereby affecting both direct support and counterfire missions.

Abbreviations

A2AD	anti-access/area denial
AARGM	Advanced Anti-Radiation Guided Missile
ABCT	armored brigade combat team
AESA	active electronically scanned array
AFATDS	Advanced Field Artillery Tactical Data System
AGM	air-to-surface guided missile
AI	air interdiction
APKWS	Advanced Precision Kill Weapon System
ASM	anti-ship missile
ATACMS	Army Tactical Missile System
AWACS	Airborne Warning and Control System
BCT	brigade combat team
C2	command and control
C4ISR	command, control, communications, computer, intelligence surveillance, and reconnaissance
CAB	combat aviation brigade
CAOC	combat air operations center
CAS	close air support

COIN	counterinsurgency
COMINT	communications intelligence
CPOF	Command Post Of the Future
DCGS-A	Distributed Common Ground System–Army
DIVARTY	Division Artillery
DMLGB	Dual Mode Laser-Guided Bomb
DMZ	demilitarized zone
DoD	U.S. Department of Defense
DPICM	Dual-Purpose Improved Conventional Munition
EFSS	Expeditionary Fire Support System
ELINT	electronic intelligence
EMARSS	Enhanced Medium-Altitude Reconnaissance Surveillance System
EMRG	Electromagnetic Rail Gun
EO	electro-optical
ERGM	Extended Range Guided Munition
ESM	electronic support measures
EW	electronic warfare
FAB	field artillery brigade
FARP	forward area refueling point
FMTV	Family of Medium Tactical Vehicles
FMV	full-motion video
FY	fiscal year
FOB	forward operating base

GBU	Guided Bomb Unit
GCS	ground control station
GLCM	ground-launched cruise missile
GMLRS	Guided Multiple Launch Rocket System
GMTI	Ground Moving Target Indicator
GPS	Global Positioning System
GWS	Gun Weapon System
HARM	High-Speed Anti-Radar Missile
HE	high explosive
HIMARS	High-Mobility Artillery Rocket System
HMMWV	High-Mobility Multipurpose Wheeled Vehicle
HVP	High Velocity Projectile
IADS	integrated air defense system
IAMD	Integrated Air and Missile Defense Architecture
IBCT	infantry brigade combat team
IFF	identification, friend or foe
INF	Intermediate-Range Nuclear Forces
INS	inertial navigation system
IR	infrared
ISIL	Islamic State of Iraq and the Levant
ISR	intelligence, surveillance, and reconnaissance
JAGM	Joint Air-to-Ground Missile
JASSM	Joint Air-to-Surface Standoff Missile
JASSM-ER	Joint Air-to-Surface Standoff Missile–Extended Range

JDAM	Joint Direct Attack Munition
JETS	Joint Effects Targeting System
JSOW	Joint Standoff Weapon
JSTARS	Joint Surveillance Attack Radar System
JTIDS	Joint Tactical Information Distribution System
LBASM	land-based anti-ship missile
LGB	laser-guided bomb
LJDAM	Laser Joint Direct Attack Munition
LLDR	Lightweight Laser Designator Rangefinder
LOS	line of sight
LRA	long-range artillery
LRLAP	Long-Range Land Attack Projectile
LTL	Laser Target Locator
MANPADS	man-portable air defense system
MLRS	Multiple Launch Rocket System
MRBM	medium-range ballistic missile
MRL	multiple rocket launcher
MS-SGP	Multi Service–Standard Guided Projectile
NATO	North Atlantic Treaty Organization
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
PERM	Precision Extended Range Munition
PhZ	Panzerhaubitz
PLI	position and location information

PNT	position, navigation, and timing
PrSM	Precision Strike Missile
RAP	rocket-assisted projectile
RF	radio frequency
ROK	Republic of Korea
SAM	surface-to-air missile
SAR	synthetic aperture radar
SATCOM	satellite communications
SBCT	Stryker brigade combat team
SDB	Small Diameter Bomb
SEAD	suppression of enemy air defenses
SHORAD	short-range air defense system
SIGINT	signals intelligence
SLAM	Standoff Land Attack Missile
SLEP	service life extension program
SOF	special operations forces
S&T	science and technology
TACTOM	Tactical Tomahawk
TAIS	Tactical Airspace Integration System
TLE	target location error
TTPs	techniques, tactics, and procedures
UAS	unmanned aerial system
UCLASS	Unmanned Carrier Launched Airborne Surveillance and Strike

UHF	ultra high frequency
VEO	violent extremist organization
VHF	very high frequency
WCMD	Wind Corrected Munitions Dispenser
WIN-T	Warfighter Information Network–Tactical
WMD	weapons of mass destruction

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From early 2002 until early 2016, the Army focused primarily on counterterrorism and counterinsurgency operations, and the field artillery branch saw considerable reduction of its force structure and a commensurate cut in modernization funding. By late 2016, aggressive moves by Russia against Crimea and Ukraine, fear of Russian coercion against the Baltic nations, an expanding Iranian military, and rapidly growing Chinese military capabilities had contributed to a change in focus, and the Army was in the process of reorienting back to conventional combat against the armed forces of another nation-state. This shift highlighted the need to take a detailed look at the state of the field artillery, long a key branch of the service when conventional combat capabilities are required.

This study focused on examining the types of capabilities that Army field artillery will need in future operations from the present into the early 2030s. The authors examined several illustrative scenarios to determine the threats that field artillery units will encounter and the types of missions the artillery will be expected to perform in the future. The authors identify the types of capability gaps that may be present in today's field artillery and recommend courses of action that the Army might take to fill those gaps and better prepare the artillery for future missions. Because virtually all operations today are joint, the study also examined the current and emerging capabilities of the other services, and the authors' recommendations on how to improve Army field artillery take into account what the Air Force, Navy, and Marine Corps can contribute in terms of air-to-ground and surface-to-surface fires.

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