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Operations Research and the United States Army: A 75th Anniversary Perspective

Greg H. Parlier

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Operations Research and the United States Army: A 75th Anniversary Perspective

by Greg H. Parlier

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This paper represents the opinions of the author and should not be taken to represent the views of the Department of the Army, the Department of Defense, the United States government, the Institute of Land Warfare or the Association of the United States Army or its members.

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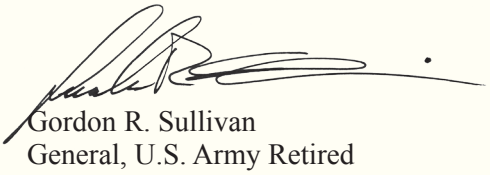
Foreword

Early during World War II, a new multidisciplinary approach to solving complex military problems was pioneered by the British during the Battle of Britain. Combining civilian scientific talent with operational staffs, initially within Fighter Command, to operationalize newly invented radar, "Operational Research" rapidly gained credibility within the Royal Air Force and quickly spread to support the U.S. Army, both ground and air forces, as well as British and U.S. naval forces.

Now, 75 years later, on this diamond anniversary of the marriage between the art of warfare and the application of the scientific method, the U.S. Army is experiencing another postwar drawdown at the conclusion of more than a decade of conflict. At a time when Operations Research (OR)—both the practice and the professional community—appears to be at a crossroads, the author forcefully argues that the current trajectory of this unique professional discipline must be properly aligned with what really needs to be done. Indeed, several ongoing and emerging conditions now warrant a comprehensive evaluation of the current state of OR within the U.S. Army.

Accordingly, this Land Warfare Paper both offers a framework for such a review and addresses past, present and future practices. Enduring principles are derived and applied to recent combat experience. Opportunities for applying strategic analytics to present challenges are described, including the need to balance the Army, especially during a period when the All-Volunteer Force may become increasingly vulnerable. Future directions are suggested that leverage traditional technology innovation, both physics-based and informational, along with new management "engines for innovation" to guide transformational endeavors during a period of inevitably disruptive change. Organization, doctrine, education and professional development are addressed. Several recommendations are offered to resurrect, restore, renew and transform OR for the U.S. Army.



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Operations Research and the United States Army: A 75th Anniversary Perspective

I believed that an increasingly complex, turbulent and unstable world required sustaining the U.S. military at a high level of capability and readiness; we just needed to be a lot smarter on how we spent our money to achieve that purpose.

Robert M. Gates,
Duty: Memoirs of a Secretary at War[1]

Introduction

As the Battle of Britain loomed early in World War II, in an occupied manor renamed Bawdsey Research Station on Suffolk's southeastern coast, a new profession was being invented. At the time, the British term coined to define this system of *teams* supporting Air Chief Marshall Hugh Dowding and his Royal Air Force (RAF) Fighter Command with the integration and use of newly-invented radar was "operational research" (OR). The fate of western civilization was at stake, prompting Prime Minister Winston Churchill to describe this period after the fall of France as Britain's "darkest hour."[2]

Current Conditions

Now, 75 years later, we are emerging from the longest sustained war in American history, facing a postwar drawdown as yet another defense resource boom-and-bust cycle occurs. This time, however, as the defense budget pendulum inevitably swings back full force, we also find ourselves on the precarious edge of a dramatic intergenerational, financial and economic abyss.

At the same time, the geopolitical landscape seems to be unraveling. The Middle East has reignited and is ablaze with an Islamic caliphate gaining hold in Syria, Iraq and Lebanon. Humanitarian crises, barbarian acts and accounts of genocide shock our senses. The only certainty in Gaza is another announced Israeli–Hamas cease fire that will soon be broken again. Iran marches on to a nuclear weapon and delivery capability. In West Africa, the largest outbreak of Ebola virus has rapidly expanded from regional epidemic to global pandemic, resulting in more than 7,000 deaths so far, spreading fear and causing the director of the World Health Organization to declare an international emergency. Meanwhile, the Islamist terrorist organization Boko Haram continues its kidnapping and killing spree, forcing half a million Nigerians to flee their homes.

After annexing Crimea, the Russian army remains poised on the border of eastern Ukraine. In the Far East, a growing and belligerent China confronts its neighbors, challenging international norms in the East and South China Seas, causing a disquieting and dangerous arms race. The history of international relations tells us that great power clashes often arise from friction between two powers, one dominant and the other growing; relations between the United States and China might well be at an inflexion point.[3] Japan has reinterpreted its "self-defense" clause and one can only wonder if North Korea will implode before it explodes. At home, the nation is overwhelmed with border security challenges and the humanitarian drama of children pouring across the southern boundary.

Two editors of the *Economist*, elaborating on "The State of the State," even suggest that the "ascendant tradition of the Western liberal democracy" may be reversing; a crisis has been brewing for decades, becoming acute in recent years due to a "toxic mixture" of increasing dependency on government and a simultaneous disdain for it.[4] One need not be a "declinist" to concur with former Secretary of State Madeleine Albright's recent observation: "The world is a mess."[5]

Finally, for some perspective across the millennia, a recent flurry of books and articles has expounded on the American condition today and similarities to ancient Rome as it transitioned from a republic to an empire: "Is America Rome?" The parallel of decadence and decline, with the rise of *latifundia* as the Roman empire expanded, acquiring incredible wealth while "importing" slave labor, gradually created both a dependent class "on the dole" and corruption among the elite. Even in the ancient mind, however, decline was not seen as inevitable but rather as a serious moral question and deliberate choice as excessive material accumulation resulted in ethical regression and moral decay.[6]

An Opportunity

Following the diamond anniversary of the marriage between the art of warfare and the application of the scientific method, America is experiencing another postwar drawdown at the conclusion of more than a decade of conflict. These conditions warrant a critical, comprehensive, introspective evaluation of the current state of military OR. Given present challenges and opportunities, is the current trajectory of this unique professional discipline aligned with *what really needs to be done?* If such an evaluation is to be undertaken, how should it be structured, organized and conducted?

This inquiry should include: (1) a forthright postmortem on the past decade and a half of war; what precisely were the contributions of OR in Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF)?; (2) an examination of the adequacy of the military's current capabilities, sufficiency of capacity and how they can best be organized, utilized and focused to address current challenges; and finally, (3) given trends and foreseeable challenges, a forward-looking appraisal of potential opportunities.

Resurrecting Our Past

A major precept of any learning organization is the ability to actually learn from and apply the past to the future rather than merely looking back to observe it. Paradoxically, a look to the past can often reinforce rather than retard innovation. As people naturally tend to see their current problems as unique and overwhelming, historical analogies can be especially helpful. They can stretch and broaden thinking, allowing contemporary challenges to come into better focus through the long lens of history.

Looking to the past for insight, one can discover principles that should be resurrected and reapplied. They can be a guide and serve as a basis to judge recent performance and contributions. What are they and how can they be used to assess the application of military OR (MOR) in OIF and OEF across the four domains of capability, capacity, utilization and contribution?

Capability: Advice, Not Just Information

Freeman Dyson, who went on to become a renowned mathematical physicist, was one of the original OR analysts attached to RAF Bomber Command supporting Air Chief Marshall Arthur Harris. Among his retrospective observations was the imperative for OR to provide senior commanders with *advice*, not just information.[7] How well has this principle been applied?

Have voluminous PowerPoint briefings genuinely facilitated understanding? Have they been used to truly *advise* commanders and staff on operational courses of action development? Or have operations analysts been viewed primarily as chartmakers, providing, at best, situational awareness (information)?

Was there a *focus on understanding critical cause–effect relationships*, then on providing advice and offering solutions to improve operational decisionmaking derived from this knowledge? A few applications come to mind:

- triage for adaptive solutions and rapid fielding across doctrinal, organizational, training and materiel domains to support the operational Counter-Improvised Explosive Device (C-IED) battle;
- connecting supply (the inventory management system) to real customer demand (readiness production for tactical units) across major classes of supply;
- relating Improvised Explosive Device (IED) activity (cause) tracked through classified database information systems—such as combined information data network exchange/ significant activities—to actual casualty results (effects) in medical joint trauma tracking systems (electronic medical record systems and joint theater trauma systems); and
- empirically identifying, tracking, understanding and then influencing critical political, military, economic, social, infrastructure and information factors underlying successful stability operations.

Was OR applied to its full potential, providing multidisciplinary perspectives and applying the scientific method to large-scale, complex systems and challenges? As Professor Dyson might ask, "Did we truly *advise* our senior leaders—or merely inform them?"

Capacity: The Power is in the Pack

Military operations analysts were assigned in significant numbers to both Iraq and Afghanistan. However, since most deployed warfighting units had few, if any, OR billets, nearly all analysts were borrowed for varying times and assigned into theater from other institutional staffs and academic organizations—e.g., the Center for Army Analysis (CAA), Air Staff A-9, the Naval Postgraduate School, the United States Military Academy, Army Accessions Command, etc.—many were then widely distributed to fill single, non-OR positions. In some of the higher headquarters, federally funded research and development center (e.g., RAND Corporation and the Institute for Defense Analyses) volunteers also filled a small number of analyst positions, yet few had OR backgrounds (education or experience), even those participants with doctoral-level degrees. Nor were contractor-filled positions in the divisions and brigades consistently

filled by personnel with OR backgrounds. While these programs relied upon volunteers, the maturity, demeanor and behavior—in addition to education and training, military experience and affiliation—all contribute to the perception in the minds of commanders and staff as to what constitutes OR. In turn, these observations inform senior leader expectations and understanding of what OR is, what OR analysts actually do and the contributions they make.

Was there enough qualified analytical capacity? Although they performed important tasks in various organizations, were OR analysts assigned to locations and elements across the commands in sufficient numbers to achieve critical mass and make a real difference? Or, were they fragmented to perform other tasks? Did senior leaders understand how to employ and use them? "OR analysts are like wolves—the power is in the pack." In recent years, both operationally and institutionally, has the profession been organized for success? Is it now?

Utilization: Swamped by Routine Activities

The final chapter of the British Air Ministry's official history of OR in the RAF during World War II notes:

> There was a danger of original work [in the various OR Sections across the RAF] being swamped by routine activities. . . . Original thinking was necessary. . . . Large amounts of statistical work brought about an inflation of staff and dilution of scientific personnel so that the section tended to lose its best research characteristics.[8]

During OIF, there was an amazing proliferation of integrated planning teams, work group circuits, command and staff calls and assorted meetings—all under the guise of battle rhythm. Once acknowledged and eventually studied, the unsurprising theoretical result was that no time remained to accomplish genuine work. Did this battle rhythm divert and distract us? Were OR analysts "swamped by routine activities"?

Considerable time, effort and energy were expended on data reconciliation for upcoming briefings. By comparison, did the large amounts of statistical work that diverted and swamped the RAF OR sections equate to captivation by data disconnect drills and routine PowerPoint chartology production? Perhaps the Latin inscription on the OIF combat analyst challenge coin was indeed far beyond battlefield humor and all too telling: *Veni, vidi, duci*—I came, I saw, I counted.

Were Soldiers diverted from actually practicing core competencies? Were they able to do what really needed to be done?

Contribution: Part of the Fighting Team

"Organizational and Procedural Problems" in Morse and Kimball's seminal book, *Methods of OR*, emphasizes:

> OR is not a pure research activity separated from all else; it is an integral part of an operating organization. . . . The [OR analyst] must be the scientific adviser of the fighting force itself . . . part of the fighting team. The OR group should therefore be assigned directly to the operating command.[9]

For the Army, following the first Quadrennial Defense Review (QDR) (1996–97) during the last major force drawdown, one of the follow-on initiatives was a special study to identify the impact of post-Cold War trends on the OR community, including growing demand for quick-turn analyses, major reductions in OR personnel and budgets and opportunities to

leverage information technology (IT). The question posed by the Army's then-Assistant Vice Chief of Staff was: Is, or should there be, a revolution in analytical affairs (RAA)? In 2001, the outcome of this RAA study was a recommendation for strategic partnering to compensate for the major manpower cuts that occurred during the 1990s.[10] Over the past decade, this strategic partnering concept was eventually operationalized in the form of both reachback and split operations between the Iraq and Afghanistan theaters, several continental United States (CONUS)-based analytical organizations, federally funded research and development centers (FFRDCs) and even academic institutions. CAA, Joint Improvised Explosive Device Defeat Organization's Chartered Analytic Program and the Institute for Defense Analyses' Focused Analyses all provide examples of this. But how well did this reachback approach for strategic partnering actually work?

For split operations, standardized *routine* chartology production (some decks numbered well over 100 charts and were prepared weekly) could be performed in the rear, thereby freeing up forward-deployed analysts to focus on analyzing and communicating the results, incorporating them where appropriate into operational plans and actually conducting genuine OR endeavors. But did this actually happen?

And while chapter IX of the CAA Deployed Analyst Handbook listed several reachback supporting agencies, was this help actually helpful? Did strategic partnering help to accomplish what really needed to be done?

A final observation, less obvious but valuable nonetheless, is that there are remarkable similarities between the newly emerging collaborative enterprise and the original organizational forms and purposes that created OR during the early years of World War II. The idea for implementing a "system of *teams*" with multidisciplinary expertise across a wide range of scientific and military disciplines—using empirical evidence from ongoing military operations in conjunction with creative scientific models for rapid learning—defined and differentiated OR. Working closely with, trusted by and responsively advising high-level commanders and leaders, all while operating under extraordinary pressures, was the hallmark of OR at its inception.

As these few examples suggest, turning to history for comparative insight into past and current conditions can be beneficial. When superimposed on these lessons learned, the underlying logic of current practices can be directly challenged; indeed, powerful observations—even first principles—can be deduced. Certainly these domains of *capability*, *capacity* and *utilization* are influenced by organizational design, thereby directly impacting *contribution*. Reflecting on the past decade, one should ask: Was the OR community structured and *organized* for success?

Perhaps the ultimate test of perceived value can be found in the acknowledgment from senior military leaders and defense officials whose decisions benefit from insight and *advice* provided by OR professionals. How have OR contributions been recognized in recent biographies and autobiographies of senior officials? Institutional contributions can be found in current military doctrine and MOR official history. To what extent is OR explicitly addressed and incorporated in our joint doctrine and field manuals? For example, what role is prescribed for OR in current counterinsurgency doctrine? Will the Combat Studies Institute try to disentangle and tackle the evolution of the IED and C-IED battle? If so, how will OR's contributions be characterized? And, since the final volume of the trilogy *The History of OR in the U.S. Army* ends in 1995, what about the official history of the profession since then?[11] It has been nearly 20 years since that conclusion; will there be a volume 4?

Present Challenges

The United States will continue to face enormous challenges over the next few decades. Beyond the more apparent international geopolitical disruptions and accompanying economic crises, a broader national security perspective must also address several other worrisome trends and their interactions. This endeavor should also be viewed from the perspective of the current national financial predicament and the ongoing quest for solvency in public policy. Despite an incredible advantage in global military power, America faces enormous strategic resource challenges on a perilous cusp of history. Current trends within the federal budget in both discretionary and entitlement programs render current spending trajectories unsustainable and future programs unachievable.

A broader national security perspective must address the foreseeable geopolitical environment, which a recent Army Chief of Staff labels "an era of persistent conflict." The *2013 Strategic Survey* from the International Institute for Strategic Studies portends a "persistent state of sublimated strategic anarchy." But America is also afflicted with disconcerting domestic sociodemographic patterns and education challenges, national infrastructure decay in energy, transportation and civil works, sagging personal savings and increasingly intractable social entitlement policies. Realistic projections of these converging trends illuminate enormous risk to the nation—a potentially catastrophic gap between future expectations and unfolding realities.

The U.S. government has been running trillion-dollar annual deficits, national debt is in the double-digit trillions and the current fiscal gap (the correct performance measure for the real fiscal condition) is an incredible $250 trillion. Traditionally, the purpose of federal debt has been to support public goods—investments with long lifespans—since borrowing spreads costs among both current and future taxpayers, both of whom benefit. Examples include national defense, domestic civil infrastructure and research and development (R&D) to support invention and improve productivity. Now, the huge and growing debt is supporting entitlements in the form of payments to individuals. Pursued on a massive scale, this diminishes rather than benefits future taxpayers. The nation is increasingly borrowing to fund individual consumption-driven personal benefits, not public goods. And this rapidly deteriorating predicament has been on legislative autopilot for several decades.[12]

Amazingly, the greatest risk to western democratic economic security seems increasingly to be America's own government financial predicaments. It is not only the financial security of the near future that is being threatened; the posterity of subsequent generations is being mortgaged and impossibly burdened. This condition in public policy is as morally reprehensible as it is economically bankrupt. It is also strategic insanity. America cannot continue along this path.

Given these broader influences on national security, the scope of the professional discipline must be addressed. Given the broader challenges to national security, has the term "*Military* OR" become too restrictive? Current concerns extend beyond a merely military focus, including geopolitical (the "clash of civilizations"), economic and sociodemographics (the "clash of generations"), global resource distribution patterns, demographic dynamics environmental shifts and, finally, the interactions among all of these issues.[13] What could a reinvigorated OR community do?

Balance: Force Structure, Training, Skill and Technology

Several QDRs have now been undertaken, yet the first is most relevant for today's conditions. Though it occurred nearly two decades ago, the challenges existing then—during

the post-Cold War drawdown—parallel several faced today: maintaining balance while reducing force levels, preventing the development of a hollow force and ensuring that there is no precipitous break in the Army that would set it up for first-battle failures in future wars. Army leadership grappled then with the critical need to maintain balance, knowing how to define, measure, design, model and actually achieve it—something that had not been done well throughout military history as Army drawdown curves have illuminated. Balance is a multidimensional concept that was pursued, both strategically and temporally, by providing for current and future readiness—more precisely, current force readiness, mid-term modernization and long-term R&D investment—while synchronizing force structure, modernization, manpower and infrastructure. These new methods for strategic analytics, crude though they were, helped to chart and resource a viable course leadership in what was called "an era of strategic uncertainty."[14]

While intuitively recognizing that training, skill and advanced technology were important factors of success in conflict, the nature of their relationship—their respective contributions and especially how they interacted—was not well understood. However, there were several trends then that were making a clear understanding of this interrelationship increasingly important.

Twenty years ago, during the mid-1990s, much of the conventional wisdom was of the opinion that America was in the midst of a so-called revolution in military affairs. Technology would provide a global command, control, communications, computers, intelligence, surveillance and reconnaissance and precision strike capability that would provide, in the words of one defense analyst, "an ability to bomb any target on the planet with impunity, dominate any ocean and move forces anywhere to defeat just about any army."[15] This suggested, in the midst of the post-Cold War drawdown and declining defense budgets (the "peace dividend"), that modernization and investment accounts should be protected, even expanded, at the expense of force structure, training and readiness during a "strategic pause." Nonetheless, while a major premise for transformation was that speed, agility and precision could substitute for mass, the unfolding reality during the emerging new world order was that eradicating root causes of contemporary (unconventional) aggression required a completely different skill set.

The "base of sand" issue in combat modeling and simulation practices also needed to be acknowledged and handled. In 1991, a group of experienced defense analysts and senior scientists from several FFRDCs, defense agencies and the scientific community boldly challenged existing military combat modeling, defense simulation and wargaming methods. They concluded that management and underlying concepts in analytical agencies were "so fatally flawed" that "anything less than structural changes in management and concept" would not be effective in correcting them.[16] Their recommendations were comprehensive and compelling—a wake-up call to the Department of Defense (DoD) analytical community.

One of the observations that instigated their efforts was the enormous gap between official model outcomes and the actual evidence of recent history. They attributed this to lack of adequate theories and a "vigorous military science," resulting in an excessive focus on modeling and simulation technology rather than the substance within.[17] For example, medical planning factors were derived from attrition-based, theater-level campaign model casualty projections. However, when compared with actual empirical evidence from recent experiences of modern warfare, including Persian Gulf War results, these projections were overpredicting aggregate casualties by orders of magnitude, thereby creating unnecessary and unaffordable requirements for medical force structure and supply support.

As a consequence of those conditions—declining budgets and the emphasis upon technocentric solutions without actually understanding or incorporating critical cause–effect relationships into models, simulations and wargames—a comprehensive historical, theoretical and empirical evaluation of past operations was launched. The fundamental intent of the endeavor was to identify and verify patterns and relationships that would provide significant predictive power for the future. An experimental design approach was developed and pursued, grounded in relevant theory, to capture the statistically significant factors influencing future demand using all of the information provided by the empirical evidence of recent experience. It was predicated on the simple notion that practical operational enhancements emerge from the judicious study of discernible reality.

These extensive, comprehensive analyses into the nature of modern warfare and the structure and patterns of resultant casualties yielded major improvements in forecast accuracy and an ability to design more responsive, effective medical support requirements that, in many cases, result in reduced force structure investments and medical materiel and supply support costs (class VIII). The resulting seminal analyses, which challenged traditional views and standard practices at the time, have since been validated and corroborated by recent experiences in both Afghanistan and Iraq. They are now being further refined and extended.[18]

This research effort has since been expanded to other classes of supply, focusing on class IX for the materiel enterprise. Spare-parts consumption patterns and readiness drivers for Army aviation fleets that either dominate or differ significantly across operational missions and geographic locations—and how they may vary from peacetime training—have been empirically identified. The major hypothesis states, "If empirically derived Class IX usage patterns, profiles and/or trends can be associated with various operational mission types, then operational planning, demand forecasting and budget requirements can be significantly improved to support a capabilities-based force." The potential for improvement is enormous.

Ultimately, despite cultural proclivity and increasing reliance on technology for solutions, it is necessary to constantly remember that a less skilled military is a far greater liability than less advanced technology. Power ultimately takes its meaning from the values and purposes it serves. During the 1990s, when General Gordon Sullivan was Army Chief of Staff, he challenged senior leadership to ensure that they did not inadvertently allow another hollow force or something even worse ("No more Task Force Smiths"). He frequently recalled Korean War historian T.R. Fehrenbach's observation:

> Americans in 1950 rediscovered something that since Hiroshima they had forgotten: you may fly over a land forever; you may bomb it, atomize it, pulverize it and wipe it clean of life—but if you desire to defend it, protect it and keep it for civilization, you must do this on the ground, the way the Roman legions did, by putting your young men in the mud.[19]

Today, in the midst of another drawdown period, American military forces are again challenged to maintain balance. Looking back to the first QDR, national security leaders must ask: should they start where they left off there, or start over?

Strategic Analytics

One of the attributes of strategic analytics is alignment of methods and models with the ends–ways–means strategy paradigm. *Descriptive analytics* are used to systematically diagnose structural disorders, perform root cause analysis and identify enabling remedies, i.e., *means*.

Integration challenges are addressed using *prescriptive analytics* to attain policy objectives and desired *ends*. Design and evaluation then incorporate *predictive analytics* to develop analytical architectures (*ways*) to guide the change management effort toward desired ends. One recurring observation from applying this "analysis, synthesis, design and evaluation" engineering and problem-solving approach to several strategic enterprise challenges is that confusion between *ends* (what is to be achieved) and *ways* (how it is to be achieved) can be uncovered and resolved.

For example, during the last major military recruiting crises in the late 1990s, the All-Volunteer Force (AVF) was at great risk, a fact not commonly remembered today. All the military services failed either their annual quantity missions or quality goals; the Army failed in both for multiple years in the active and reserve components. Forecasts for future economic conditions, youth market demographic patterns and propensity, resources available and near-term recruiting requirements needed to achieve Army manpower and readiness goals made it clear that the AVF could not be sustained in its existing form. Projections were truly dire; the phrase used to describe the situation was "imminent catastrophic failure."[20] Every effort was made to salvage the AVF concept. Massive and difficult reengineering was required and undertaken. But what became crystal clear then—and is worth noting now given current and foreseeable trends—is that leaders were forced into the realization that while the internal objective is to man the Army, the Army's larger purpose is to serve the nation. The AVF was then, and is now, a *way* to achieve those *ends*; the AVF should *not* be viewed as an end unto itself. It is one of many military manpower systems (*ways*) that can be considered to reconcile means with ends. From World War II until 1999, at least five different manpower recruitment systems have been used or seriously considered; in 1999 leaders were forced to seriously consider a sixth (it was not a return to the draft). Although the AVF was able to be salvaged then, there were initially no guarantees that those new concepts, initiatives and changes—many still in place today—would succeed. But they were also designed to allow a graceful transition to the alternative had they not been successful.

Once again today, the AVF in its current form is becoming unsustainable.[21] "Imminent catastrophic failure" will likely be on the horizon soon.[22] Strategic analytics can be used to illuminate a better *way* ahead—perhaps a uniquely American way.

In addition to cost growth in manpower and personnel (force structure "capacity"), there has also been considerable growth in operating and support costs (force readiness "capability"). These are the two largest categories in the defense budget—nearly 75 percent. From a historical perspective, they have been dramatically reduced in postwar budgets to achieve the near-term savings needed to meet drawdown targets.

To the extent that significant savings can now be generated from within the institutional support enterprises—man and train, equip and sustain—at least some of the force structure that will otherwise be eliminated could instead be retained. For example, internally transferring savings obtained from a more efficient materiel enterprise (equip and sustain) by transforming military supply chains could help to preclude reemergence of a hollow force caused by the deleterious effects, especially for the Army, of the boom-and-bust drawdown cycle.

Although they were masked by the massive infusion of resources for much of this last decade, persistent supply management problems and inadequacies that existed more than ten years ago are again becoming apparent. Indeed, for nearly a quarter-century now, these issues—including the inability to relate resources to readiness due to lack of strategic plans, poor inventory management and fragmented supply chain operations across the materiel enterprise—have been so

glaring and enduring that they have remained on the Government Accountability Office's high-risk list *every year since 1990*.[23] Furthermore, the promise for improved performance attributed to large investments in IT solutions in the form of enterprise resource planning (ERP) systems that have been installed in recent years has not been realized, continuing to plague the military as a whole. Now again, with overseas operations abating, the budget pendulum swinging back with mounting pressures to generate savings and find efficiencies and the adverse effects of the national fiscal reality rapidly converging, the quest for more efficient, cost-effective operations is returning. A phrase to describe this goal is *cost-wise readiness*.

OR and management innovation could be used in imaginative ways across the materiel enterprise to better relate resources to readiness, generate significant savings, improve readiness and preclude another hollow force that would invite rather than deter aggression. One recent comprehensive study suggests this can be achieved using decision support systems empowered with advanced analytics, including dramatically improved demand forecast methods (e.g., mission-based forecasting), sensor-based technologies for proactive parts replacement (e.g., connecting condition-based maintenance to the supply chain) and integrating supply chain optimization methods (e.g., multi-echelon readiness-based sparing) in conjunction with enterprise IT data platforms and repositories (e.g., the logistics modernization program and the Global Combat Support System–Army.)[24]

Costs savings for these various advancements have been estimated to be at hundreds of millions of dollars. Their combined effects, once fully implemented, will likely save billions, resulting in a return on investment of several orders of magnitude. Furthermore, it would become possible to better "relate resources to readiness" across the DoD materiel enterprise that annually consumes over $150 billion in maintenance activities, inventory procurement, distribution and sustainment costs; current year budgets can be credibly correlated with tactical equipment readiness and programs to future capabilities.[25]

In this era of dramatic fiscal challenges, major budget reductions and defense resource constraints, harnessing and applying the full power of analysis—OR and strategic analytics—across institutional supporting enterprises must be implemented both to preclude another hollow force *and* to achieve cost-wise readiness.

Future Directions

Looking to the future, what are some of the opportunities that could further empower OR across a broader context of national security?

During most of its existence, the OR community has been limited by both data challenges and computational power. Now both are clearly changing in this new digital technology era of big data. Indeed, data has become ubiquitous; the challenge now is to somehow make sense of it all. Just as diminishing returns finally seemed to be dampening Moore's Law on computing power, the Los Alamos National Laboratory demonstrated the first supercomputer to achieve a petaflop of sustained performance—a million, billion calculations per second and 1,000 times faster than the existing teraflop standard. And last year Stanford researchers announced creation of a computer using carbon nanotubes that allegedly can even further improve performance by an order of magnitude over silicon chips.

So, these twin banes of our past—data and processing power—are now more likely to offer opportunities than to limit capacity to support emerging analytical capabilities. There is already a link between big data and analytics, the extensive use of data, statistics and quantitative

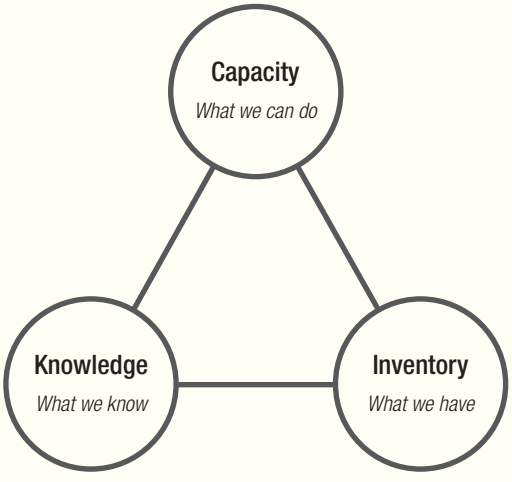
algorithms for descriptive (explanatory), predictive (forecasting) and prescriptive (optimization) modeling and analyses for fact-based, analytic management. Through sensor technology (digital source collectors), radio frequency identification, total asset visibility, ERP systems and the Internet, IT has expanded to capture, track, monitor and make visible data in near-real time across disparate, dislocated entities comprising an entire enterprise.

However, analytical architecture has not yet been fully integrated into enterprise system challenges. Complementary decision support systems have not yet been developed. Yet they could capitalize on all this enterprise data and, using analytically-based methods, *make sense of it all*, enabling improved decisions for dramatically improved enterprise performance.

If uncertainty is viewed as the complement of knowledge, then for a fixed demand the three quantities shown in **figure 1** (inventory, capacity and knowledge) are substitutes in the following sense: If more of one is available, then less of one or both of the others is necessary for the same level of system performance needed to meet that demand. This trade-off suggests a fundamental truth: If the amount and timeliness of useful data and good information for actionable decisions improves (i.e., increased knowledge or "what we know"), then with the same capacity as before ("what we can do"), it now becomes possible to improve system performance with fewer resources ("what we have").

Figure 1: Capacity, Inventory and Knowledge

Substitutable Ingredients of System Performance



Hence, for large-scale complex organizations, the greatest return on investment is derived from incorporating relevant analytical tools (OR) *with* the appropriate IT—IT that enables and provides the decision support needed to achieve cost-effective, performance-oriented results aligned to strategic plans, organizational vision and *the purpose for which the enterprise exists*. The goal should be effective integration of analytics into organizational decisionmaking. How can this goal be achieved?

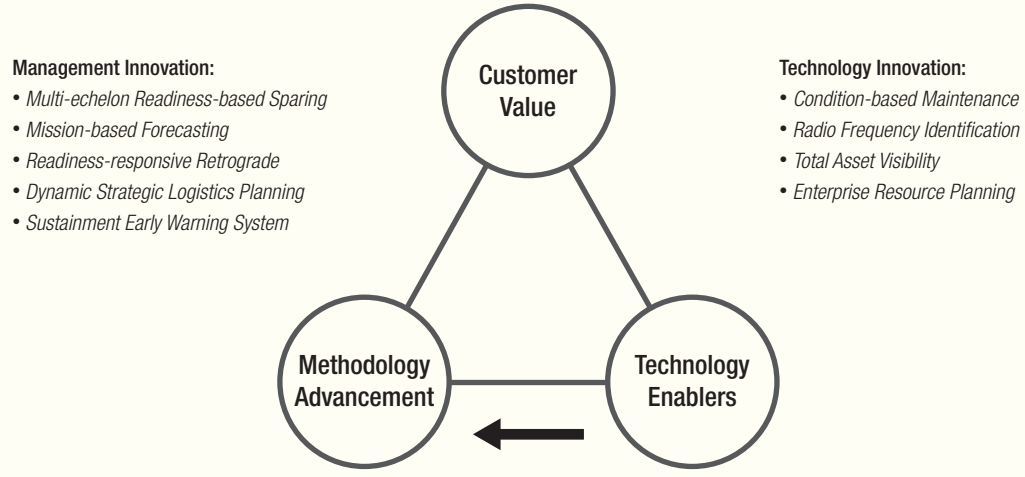
Transformational Analytics: Management Innovation as a Strategic Technology

While improvements in data storage, transfer and processing have been astonishing, most organizations struggle to manage, analyze, apply and transform data into useful information for knowledge creation and actionable decision options. The corporate world has come to realize that proceeding with new IT systems investments, without first examining and implementing needed business process changes simply automates existing inefficiencies, resulting in negligible benefits. The term "business intelligence" is now used to encompass both analytics and the data processes and technologies used for collecting, managing and reporting decision-oriented information. Nonetheless, analytic management is often impeded by organizational pathologies: conventional wisdom crowds out critical thinking; high-level managers fail to demand rigor and dispassionate analysis; and organizations lack the capacity for empirical work. It is necessary to create the analytical capacity for insight, refinement and better decisionmaking.

Although theoretical development and empirical studies needed to link comprehensive analytical approaches to business performance are still relatively immature, we must be wary of

so-called IT solutions. Rather, information systems—*especially enterprise resource planning systems*—must be connected to analytics to create decision support system (DSS) capabilities. As mounting evidence suggests, the source of real advantage is *not* obtained merely by procuring IT "solutions," but rather organizational capacity to create insight and decision options from growing amounts of information and improved situational awareness made available by these advances in information systems technologies. See **figure 2**.

Figure 2: Management Innovation as a Strategic Technology



Although those so-called IT solutions have ubiquitous appeal and enormous investment levels, without using the analytical, integrative power of OR to focus business process reengineering on desired outcomes, this obsession with IT results in growing complexity and information overload that exceeds interpretive capacities of organizations responsible for developing and using them; this has been termed "ingenuity gap."[26] A complementary relationship between DSS and management information systems—both symbiotic and synergistic—is needed.

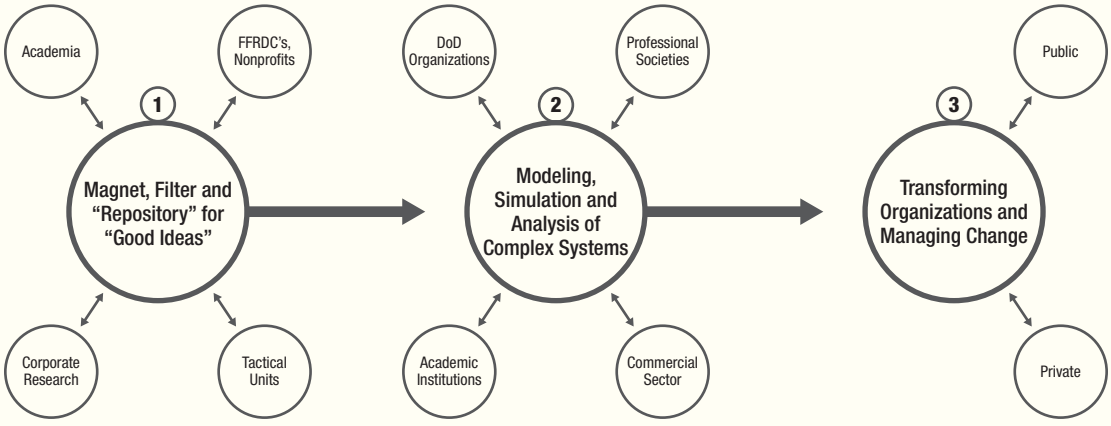
Analytical Architecture and Engines for Innovation

Two distinctly different planning approaches can be distilled from the management literature: first, the traditional or incremental approach, and second, a transformational perspective. The traditional approach focuses on a short-term (annual) horizon where internal budget constraints and financial targets constitute the primary management objectives of defending and extending existing business. For stable environments with growing market potential, this familiar incremental approach can yield steady business growth. In contrast, the transformational perspective orients on penetrating emerging markets and creating new ones. This externally-focused approach views environmental conditions and future challenges as potential opportunities rather than constraints to existing business. Since past performance becomes increasingly irrelevant as a benchmark for planning objectives, an organizational vision must be imagined for a future horizon and creative plans developed to engineer progress toward this future vision. In this sense, transformational strategic planning requires anything from imagination to pulling organization forward, rather than pushing it toward past practices.

Key ingredients for successfully pursuing a visionary strategy include an engine for innovation (EfI) and strategic architectures for analysis, management and planning (STAAMP). A virtual test bed can provide a synthetic, nonintrusive environment for experimentation and

evaluation of innovative ideas and concepts. This synthetic environment, or microworld, guides and accelerates transformational change along cost-effective paths, providing the analytical glue to integrate and focus what otherwise would be disparate initiatives and fragmented research efforts. In essence, such a capability functions as an engine for innovation to sustain continuous performance improvement.

Figure 3: An "Engine for Innovation"



DoD – Department of Defense | FFRDC – Federally-Funded Research and Development Center

The organizational construct (see **figure 3**) for the EfI includes three core competencies:

1. a research model and supporting framework including a strategic outreach mechanism, to function as a generator, magnet, conduit, filter, clearinghouse and database for good ideas;
2. a modeling, simulation and analysis component that contains a rigorous analytical capacity to evaluate and assess the improved performance, contributions and associated costs that promising good ideas might have; and
3. an organizational implementation component to enable the transition of promising concepts into existing organizations, agencies and companies by providing training, education, technical support and risk reduction/mitigation methods to reduce operational and organizational risk during periods of inevitably disruptive transformational change.

Respectively, these three components:

1. encourage and capture a wide variety of inventions;
2. incubate those great ideas and concepts within virtual organizations to test, evaluate, refine and assess their potential costs, system effects and contributions in a nonintrusive manner; and
3. rapidly transition those most promising into actual commercial or governmental practice.

Within the U.S. Army, tactical units are renowned for pioneering and refining the after-action-review concept as a continuous learning method to surface, diagnose and correct deficiencies to improve and sustain operational excellence. Yet comparable diagnostic effort has not been prevalent at strategic levels within the institutional Army bureaucracy. As analytically rigorous autopsies on management issues are not routinely performed to learn from mistakes, reactive firefighting seems to be the persistent response to visible symptoms.

The need for institutional adaptation and agility requires a culture of innovation. However, sources for innovation must exist for such a culture to embrace. An EfI provides such a source by building a capacity for low-risk, low-cost experimentation using a synthetic environment where analytically rigorous cost–benefit analyses can be performed to differentiate between desirable objectives and attainable (affordable) ones that can actually be implemented.

The purpose of this deliberate, cyclical discovery process is to sustain continuous improvement through experimentation, prototyping, field testing, feedback and, especially, rigorous analysis. Vision and analytics must not be viewed as mutually exclusive paradigms. Rather, analytics should link organizational vision to operational results by defining and monitoring metrics tied to strategic enterprise objectives and aligning incentives to objectives. In organizations with strong cultures, especially the military, it is critical that incentives for behavior and performance are in the right places to attain desired institutional outcomes.

Also, strategic planning and management frameworks are essential to enable learning within organizations and to ensure that strategies achieve intended operational results. STAAMP visually portrays relationships between system-wide goals, supporting objectives and strategies to pursue these objectives. They also illuminate the need for adaptation and change by providing mechanisms to sense the need for reacting to as well as creating necessary change.

Strategy, then, is fundamentally about dealing with change. It represents the heart of management. Despite the inexorable advance of technology (both physics-based and information-based), it will be improved decision support systems for enterprise management, pursuing future-oriented visions linked by transformational strategic plans, that ultimately enable innovation potential to be realized.

To capitalize fully on advances in IT and rapidly growing big data challenges, applying the complementary power of OR, advanced analytics and management innovation for dramatic performance improvement, including cost savings on the order of many billions of dollars, could provide enormous contributions at a crucial time. Transformational analytics, enabled by engines for innovation, can generate and sustain continuous improvement in increasingly resource-challenged environments. Recognizing these needs and then developing the capacity to achieve them are the first steps toward *management innovation as a strategic technology (MIST)* for defense enterprise bureaucracies and, perhaps, the broader national security community.

How can building, developing, manning and leading multidisciplinary analytical teams—confronting increasingly more demanding transformational challenges in large, complex commands and organizations—occur? A possible future direction for the defense OR community is organizing these EfIs and adopting, applying and refining MIST to enable and accelerate innovation.

Organization, Doctrine, Education and Professional Development

While guidance on professional development, assignment qualification policies and standards for promotion exists, does doctrine adequately explain and convey the role of OR, i.e., purposes, expected contributions, organization and utilization? Does joint doctrine exist? If not, should it?

Are OR organizations and associated elements properly positioned across the national security bureaucracy, including combatant commands, operational commands and institutional enterprises? Are they stable, or are they undergoing constant reorganization, providing only the illusion of progress while actually inducing cultural amnesia?

Is OR adequately represented by the appropriate senior-level personnel and Joint Staff officials who provide executive oversight, guidance and advocacy? In the case of the Army, the position of Deputy Under Secretary of the Army (OR) was abolished 10 years ago. Recent advisory boards (e.g., Defense Science Boards, Decker–Wagner Acquisition Study) have attributed several adverse trends to the loss of this position and strongly recommended its re-establishment. Should this position, or something comparable, be authorized? Are the various OR proponent offices providing useful contributions, or merely administrative support? And are they guided by experienced and knowledgeable advisory boards that can identify issues and offer constructive solutions?

There are strong undergraduate and graduate educational programs that provide good training in the techniques of the trade: probability and statistics, optimization, modeling and simulation—the science of the military profession. But what about the art of that profession? Is pertinent history taught, illuminating how the practice was originally conducted and how it has since evolved to influence executive decisionmaking? For example, are the organization, use and contributions of OR teams during World War II—and how these characteristics evolved in subsequent conflicts—properly studied?

Justifiably, various officer professional management systems have evolved differently across all branches of the military over the years, sometimes prodded by Congress (e.g., Goldwater–Nichols Act of 1996): single-track; dual-track; and, for the Army, now with an officer personnel management system, a two-phase sequential-track with basic branch development in company-grade years followed by *either* branch continuation *or* functional area development and assignments during the field-grade years but not both. Are these effective? Does the flag and general officer corps have experience with and understand how to effectively use OR? Since most are not OR analyst/leaders themselves, where do they learn those skills? Defense Acquisition University for the acquisition corps? And what about the civilian Senior Executive Service corps? Or is all of this left to on-the-job training?

How can the nation better capitalize and leverage the National Science Foundation, National Academies of Science and Engineering and the various defense and service science boards to better link and coordinate the technical and scientific more efficiently with our operational, educational and analytical communities? And, most especially, what unique contributing roles should professional societies offer to assist and empower professional development, including training courses and certification, capability maturity assessment models, publications, meetings and conferences, networking, communities and special interest groups, awards and recognition, professional resources and outreach?

Restoration and Renewal: A Way Ahead

The contrast between what has been occurring and what should be done now could not be more stark. The underlying logic of current practices must be directly challenged. Significant organizational change has always provoked resistance, which should naturally be expected. Nevertheless, as observed by distinguished and esteemed historian Barbara Tuchman, pursuing flawed and failed policies *knowing* that plausible alternatives and better options are available is truly "the march of folly."[27]

Leaders *must* organize the OR community for success. They need to better coordinate, integrate and focus analytical horsepower on pressing domestic and global challenges that confront the nation. They must assess the trajectory of this unique profession and examine the adequacy

of current capabilities, capacity and organization to better address these growing challenges. Where does the profession *need* to be going?

Much of the inductive perspective that characterized traditional OR has been lost, including its empirical focus, modeling rigor and a penchant for scientific experimentation. Despite a unique multidisciplinary approach, research is retreating from real-world applications. Research, teaching and practice are increasingly disengaged from one another. As other observers have noted, the OR and Management Sciences (MS) "ecosystem" is afflicted with a "vicious cycle of estrangement" and needs improved interaction among the education, practice and research communities.[28]

Academic advancements *must* be better linked to real-world problems to bridge sound theory, engineering design, management concepts and effective practice. Strong value propositions are needed with supporting relationships among academia, government agencies and the corporate sector to better recognize OR's unique capabilities and apply them to existing and anticipated challenges. There are enormous opportunities and significant, yet unrealized potential, for dramatic improvement.

Military leaders *must* capitalize on the exploding big data environment and the surging analytics movement to promote their unique, multidisciplinary profession, expand its reach, application and contributions to these pressing challenges of the times. OR must be focused and applied to improve decisionmaking for large-scale, complex systems and organizations. This is an especially acute need for government agencies that are under increasing budgetary pressures while also suffering the stresses of block obsolescence in their workforces. Feasible policy options *must* be generated, evaluated and recommended. Analytical architectures will be needed to illuminate paths forward and to overcome increasingly partisan gridlock in political institutions and bureaucratic paralysis in government agencies. The OR profession should—indeed *must*—help guide the nation through what will undoubtedly be a period not only of great turbulence and disruption but also of tremendous opportunity.

Today, there is again a struggle to maintain balance, over time and across military capabilities, in an era of dramatic fiscal challenges, major budget reductions and defense resource constraints. During these next crucial years when the state of military OR appears to be at a crossroads, the full power of analysis—OR, strategic analytics, management innovation—must be harnessed and applied across the national security establishment to both preclude another hollow force *and* achieve cost-wise readiness. To ensure that America remains an enduring power, relevant analytical capacity as a core competency for military operations, defense strategy and international security policy *must* be restored and renewed.

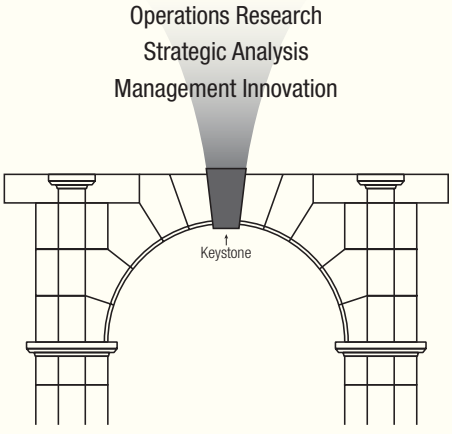
OR and MS professionals *must* be challenged and encouraged to apply their considerable strategic planning acumen, integrate their intellectual capacities, focus the power of diverse and transformational analytical capabilities and bring them all to bear on these contemporary challenges. Leaders *must* develop guiding visions and plans for such endeavors, work closely to assemble teams, and then challenge this unique profession to organize for success and pursue viable contributions. In this disconcerting and perilous time, the nation and partners across the globe would benefit from such a commitment.

A comprehensive evaluation of continuity and change in MOR should be undertaken. Where is this critical competency today? Where should this unique profession go from here? OR must be resurrected, restored, renewed and transformed; indeed, all are urgently needed.

A Future Retrospective

To conclude, there is one analogy from the ancient Roman Empire that should be highlighted for the OR profession. Today the Roman arch and its pervasive contribution to architecture and design are taken for granted. The voussoir arch was truly a brilliant feat of engineering. Prior to its invention, any long span over a horizontal distance, a bridge for example, became vulnerable to collapse with increasing load and weight. And there was a design contradiction: as the rigid span was thickened (with additional rock, brick or timber) to support greater loads the span itself became heavier and was weakened rather than strengthened. The voussoir arch with its wedges and center "keystone" circumvented this paradox. Due to its wedge-shaped design, the structure's load was transferred through the voussoir wedges then distributed down into the pillars on the sides of the arch. Thus, the structure was actually strengthened with greater loads rather than weakened, with the center keystone driving the wedges of the arch together more tightly (**figure 4**).

Figure 4: The Voussoir Arch



Although the voussoir arch was believed to have been designed originally by the Greeks and Etruscans, it was the Romans who adopted, refined and implemented the design, then spread the technology far and wide across the empire. It was used in bridges, aqueducts, temples, domes, amphitheaters and, of course, in the Colosseum, much of which still stands nearly 2,000 years after it was built.[29] Countless architectural remnants are still visible throughout Rome and Italy, across Europe and the Levant.

OR and Transformational Analytics can be the critical keystone of today, becoming stronger, more valuable in use and widespread in implementation as geopolitical and domestic tectonic pressures of the modern era increase. They can provide the glue needed to coordinate, orchestrate and pull organizations and enterprise endeavors together to keep them focused, continuously improving and learning while under increasingly greater pressure, precluding chaos and decline during an inevitable period of transformational change.

The years ahead will surely be challenging times for the United States of America—perhaps different in kind but not unknown in degree in the nation's history. The crises may be increasingly threatening and grave, but it cannot be more formidable than others already faced in the past. To keep things in historical perspective, and for inspiration, three recent books are well worth the read: *Freedom's Forge* (Arthur Herman); *Engineers of Victory* (Paul Kennedy); and *Blackett's War* (Stephen Budiansky).[30]

Twenty-five years from now will be the celebration of the centennial of this unique profession. What will volumes four and five of *The History of OR in the U.S. Army* have to say? Will they exist? Perhaps a retrospective then, echoing Churchill's characterization of the Battle of Britain, will regard this incipient period as both our darkest and our finest hour.

Glossary

AVF	All–Volunteer Force
CAA	Center for Army Analysis
C–IED	Counter-Improvised Explosive Device
CONUS	Continental United States
DoD	Department of Defense
DSS	Decision Support System
EfI	Engine for Innovation
ERP	Enterprise Resource Planning
FFRDC	Federally Funded Research and Development Center
IED	Improvised Explosive Device
INFORMS	Institute for Operations Research and the Management Sciences
IT	Information Technology
MOR	Military Operations Research
MORS	Military Operations Research Society
MS	Management Sciences
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
OR	Operations Research
QDR	Quadrennial Defense Review
R&D	Research and Development
RAA	Revolution in Analytical Affairs
RAF	Royal Air Force
STAAMP	Strategic Architectures for Analysis, Management and Planning

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