Strategic Analytics: Modeling and Simulation for National Defense and International Security

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ABSTRACT

This presentation focuses on the future of the Military Operations Research profession. Where do we need to be going? What should we be doing? How can we address, in imaginative and creative ways, persisting and seemingly intractable regional and global security challenges that confront us? Strategic Analytics, the alignment of analytical methods and OR models with the "ends-ways-means" strategy paradigm, is introduced. To fully capitalize on advances in information technologies and rapidly growing analytics opportunities, the complementary power of Operations Research, data sciences, and management innovation will be essential. Foundational building blocks for Strategic Analytics are presented: decision support capabilities, engineering systems, dynamic strategic planning, "engines for innovation", and analytical architectures to encourage and guide transformational endeavors. As illustrative examples, three recent applications of Strategic Analytics to US Army enterprise system challenges are described: defense resource planning, global logistics supply chains for materiel readiness, and recruiting an All-Volunteer Force. Strategic Analytics integrates our intellectual capacity, considerable strategic planning acumen, diverse analytical skills, and brings them all to bear on contemporary security challenges.

ABOUT THE AUTHOR

Greg Parlier is a retired US Army Colonel. A career Air Defense Artillery (ADA) officer, he served three tours as a paratroop leader and combat commander in the legendary 82nd Airborne Division, completed five deployments, supported 14 named operations, performed operational missions and training in more than 20 foreign nations. He was the first ADA officer designated an All-American Centurion by the 82nd Airborne Division Association. His assignments also included each of the Army Operations Research (OR) "areas of concentration": combat operations and land warfare analyses; manpower and personnel; test and evaluation; resource management; logistics and materiel systems; and teaching OR at West Point. His unique qualifications and expertise include building, developing, and leading multi-disciplinary teams confronting increasingly more demanding transformational challenges in large commands and complex organizations. When he retired he was the Army's senior OR officer. His contributions to the practice and discipline of Operations Research span five decades in leadership and management, strategic planning, organizational innovation, and include teaching, research, publications, and service as an academy professor, university research scientist, and professional society leader at local, state, regional, national, and international levels. For the past seven years he has been adjunct Professor of Operations Research at NC State University. Greg was founding president for the Operations Research Society of Alabama, director and vice president for the Military Operations Research Society (MORS), and past president of the Military Applications Society of the Institute for Operations Research and the Management Sciences (INFORMS). For the last decade he has chaired the annual series of International Conferences on OR and Enterprise Systems (ICORES). With advanced degrees in engineering, OR, and international security, Greg is an Army War College graduate, distinguished graduate of the USMC Command and Staff College, holds a certificate in political philosophy from Oxford, and was a National Defense Fellow at MIT.

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HISTORICAL ROLE AND CONTRIBUTIONS OF MILITARY OPERATIONS RESEARCH

Early during World War II, a new multi-disciplinary approach to solve complex military problems and encourage innovation was pioneered by the British. "Operational Research" (OR) combined civilian scientific talent with Royal Air Force military staffs, initially to support Fighter Command's urgent preparations for what would become the existential Battle of Britain. OR 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.
There is much to learn, including enduring principles, from these early World War II years when OR was conceived to integrate new technology (then recently invented radar) into combat systems, operational command and control for the Royal Air Force, and strategic air defense during the Battle of Britain. The idea for rapid learning using a "system of teams" defined and differentiated Operations Research at its inception. With expertise across a wide range of scientific and engineering disciplines, using empirical evidence from ongoing military operations in conjunction with creative mathematical models for rapid learning, OR represented a technological advancement unique in the history of military decision-making. Working closely with, trusted by, and responsively advising high-level commanders and government leaders, all while operating under extraordinary pressures, was the hallmark of OR from its very beginning.

Contributions from the *practice* of Operations Research subsequently encouraged OR as an academic *discipline* formally taught at the undergraduate level in our military academies and the graduate level in our major research universities. Since its inception, and despite some inevitable philosophical and pedagogical battles along the journey, the profession of Operations Research – both the practice and discipline – has flourished. Nonetheless, rather than investigating past technical accomplishments, significant as they surely are, this essay instead orients on the future *practice* of our Military Operations Research (MOR) profession: What do we need to be doing? Where *should* we be going?

Our national security concerns today extend well beyond an exclusive military focus to now include geo-political, geo-economic, and socio-demographic considerations, as well as energy security, population migration, environmental shifts, and various interacting dynamics among all these challenges. These broader influences on national security, including regional competition, global tensions, *and* especially domestic conditions, suggest the scope of our professional discipline must be addressed. This expanded view of national security indicates the term "*military"* OR has become too restrictive.

Now, 85 years later and following two decades of counter-insurgency conflicts, we are experiencing another transformational challenge on a dangerous cusp of history. Successfully integrating emerging technologies into weapon systems, operational concepts, and strategic plans is a central challenge confronting military innovation. Today, as then with the example of radar, we are confronted with comparable challenges to integrate emerging technologies into combat platforms, systems, and strategies: robotics and autonomous systems; artificial intelligence and machine learning; micro-electro-mechanical systems and nanotechnology; hypersonics and directed energy.

At a time when Military Operations Research—both the practice and the community— appears to be at a crossroads, the trajectory of this unique problem-solving discipline must be realigned to current and foreseeable challenges. Indeed, ongoing trends and emerging conditions now warrant a comprehensive evaluation of the current state of Military OR. Our defense establishment, in particular the US Army, must learn from its own Operations Research heritage and then fully capitalize on its promise.

THE STATE OF MILITARY OPERATIONS RESEARCH

With respect to OR contributions to broader Army challenges today, the persisting conditions described above are symptomatic of similar, pervasive conditions across an entire Army that continues to suffer from the post-Cold War decline of OR professionals, both federal civil service employees and especially the commissioned officer corps. Although the evidence for this has been irrefutable for over two decades now, there seems to be growing awareness and understanding of the widespread impact of this loss to both the operational and institutional Army. An analytical renaissance is desperately needed, long overdue, and a precondition for restoring combat overmatch and significant improvement within all major enterprise systems that comprise the US Army.

Furthermore, a comprehensive assessment of the state of Operations Research has not been conducted in over two decades. The need for a comprehensive, forthright evaluation has become evident, especially given the paucity of existing analytical capacity allocated to various commands and organizations. Without introspection to generate a clear diagnosis, an effective prescription to pursue a cure will remain elusive.

A major precept of any learning organization is an ability to genuinely *learn* lessons from the past and then actually apply them, rather than merely observe them. Such a retrospective can reinforce rather than retard innovation by discovering enduring principles that should be resurrected and applied. One possible framework to rigorously assess the current state of operations analyses in military organizations is to apply enduring principles derived from the early experience of Operations Research during World War II, among them: capacity; capability; organization; utilization; and contribution (Parlier, 2015). The Army must learn from its rich Operations Research heritage in order to fully capitalize on its promise now.

We need to coordinate, integrate, and focus our analytical horsepower on the pressing national and international security issues we increasingly face. We must assess the trajectory of our professional discipline by examining the adequacy of our current capabilities, capacity, organization, and contributions to address defense challenges of our time (Parlier 2015). Recognizing these challenges, along with evolving trends we can discern, what would a forward-looking appraisal suggest? What could a more expansive, re-invigorated *national security* OR community do?

Now, following the diamond anniversary of OR, we are emerging from the longest sustained war in American history. Facing post-war pressures during a period of increasing global tension and turmoil, our Nation confronts enormous challenges over these next few decades. At a crucial period when the "state of military OR" appears to be at a crossroads, we must harness and apply the full power of analysis – OR, data analytics, management innovation – across our national security establishment in these turbulent, uncertain times. Given the challenges we now face and the opportunities we can discern, is the current trajectory of our unique community aligned with what really *needs* to be done? What *can* our military operations research community do?

OPERATIONS RESEARCH AND STRATEGIC ANALYTICS

Military organizations, especially successful ones, are renowned for their strong cultures. Yet the long history of military innovation reveals those cultures can also become impediments to organizational adaptation when failure looms. Organizational change has always provoked resistance, especially in large bureaucracies that require conformity. And, of course, our collective human nature tends to procrastinate until crises are upon us. To overcome both bureaucratic inertia and paralysis induced by disruptive chaos, cultures must have sources of innovation they can embrace. Some mechanism, or methodology, is needed to challenge the underlying logic of current practices, and to also demonstrate better ways ahead that will accommodate graceful transitions rather than catastrophic or slow-motion failures. "Strategic Analytics" can provide such an architecture.

Although scientific advancements continue to amaze us, we must better understand how technology, management, and policy interact in our complex socio-technical enterprise systems. Management innovation often lags technology advances, yet is essential to fully capitalize on rapidly growing big data opportunities. This new Strategic Analytics framework aligns the "ends-ways-means" strategy paradigm with corresponding prescriptive, predictive, and descriptive analytics domains, focusing on the ultimate purpose for which an organization exists. Descriptive analyses segment problems, diagnose structural disorders, and identify enabling remedies and potential "catalysts for innovation" ("means"). Next, a system-wide integrating

perspective – synthesis - addresses the attainment of enterprise goals and objectives (desired "ends") using prescriptive analytics. Finally, the design and evaluation phase provides comprehensive roadmaps using predictive analytics to create "analytical architectures" ("ways") to measure progress and guide transformation.

Another guiding principle inherent in Strategic Analytics is portrayed at Figure 1. The three quantities shown (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. 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 ("what we can do") as before, it now becomes possible to improve system performance with fewer resources ("what we have").

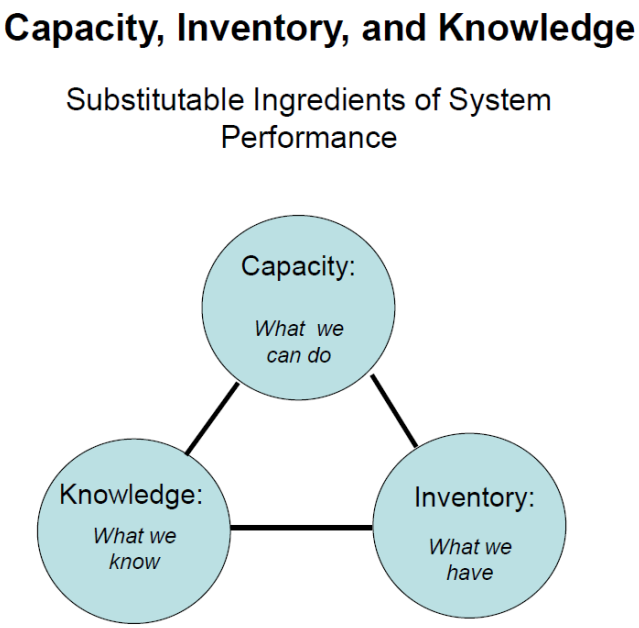


Figure 1. Capacity, Inventory, and Knowledge

Strategic Analytics also encourages shaping innovative policies and strategies around new concepts and technologies. As we look to the future, what are some of the analytical concepts and multi-disciplinary capabilities that could further empower OR across a broader context of national security?

Building Blocks for Strategic Analytics

Among the enabling disciplines, capabilities, and methods for Strategic Analytics are decision support methods, engineering systems, dynamic strategic planning, and "engines for innovation" to enable rapid experimentation, generate insight, climb steep learning curves, and develop strategies around new concepts and technologies. Although so-called "IT solutions" have ubiquitous appeal and enormous investment levels, we need to include analytical architecture for enterprise challenges. Without the integrative power of OR to focus process re-engineering on desired outcomes, this obsession can result in growing complexity, overwhelming the interpretive capacities of organizations. Ultimately, it is management innovation that will enable better decisions from the growing amounts of information and improved situational awareness made available by advances in information technologies. The goal should be effective integration of analytics into management policies by

incorporating relevant analytical tools (OR) with the appropriate IT. Acknowledging these needs and developing the capacity to address them represent first steps toward Strategic Analytics.

Many of our systems seem fragile and vulnerable, increasingly subject to catastrophic failure due to age and decay, human error, or what is known as "tight-coupling" in complex systems. And, while traditional engineering methods optimize performance based upon design specifications within assumed operating environments, experience and history reveal that these systems, and how they are used, change over time often in unanticipated ways. This recognition is now leading to new design and management concepts where flexibility across a range of future possibilities, rather than optimizing to a specific assumed environment, is needed to accommodate inevitable change. Thus, a capacity for adaptation must be "built in" to create a resilient system that can adjust as needed.

Just as nanotechnology is increasing our understanding of very small-scale structures, the evolving discipline of Engineering Systems is expanding our macroscopic understanding of very large-scale enterprise systems defined by their technical, managerial, and social complexity. Engineering Systems represents the next epoch of scientific innovation beyond inventions and complex systems. This new and evolving approach represents a new paradigm in systems design by shifting from the traditional focus on fixed specifications, or "requirements", toward the active management of uncertainty in the implementation of socio-technical systems (deWeck, Roos, and Magee, 2011).

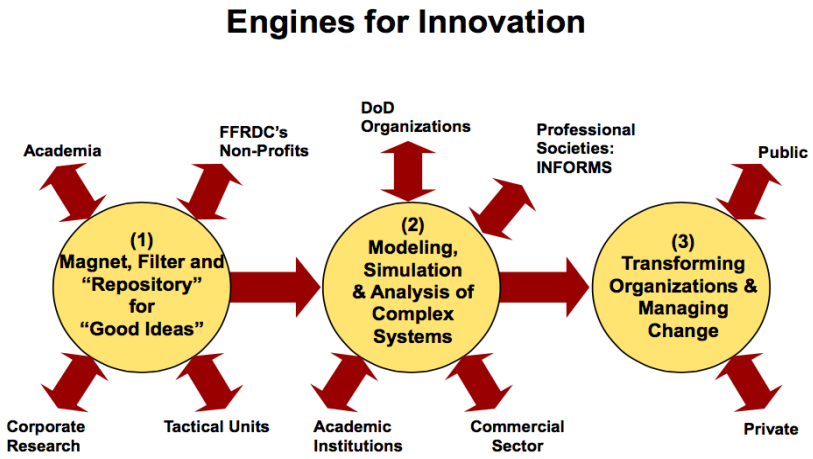
Most system design methods generate a precise, "optimized" solution based on a set of very specific conditions, assumptions, and forecasts. However, these methods are rarely valid over longer planning horizons as strategic designs for technological systems. In contrast, Dynamic Strategic Planning (DSP) instead presumes forecasts to be inherently inaccurate and therefore generates flexibility as part of the design process. This method incorporates optimization techniques and decision analysis methods, and has evolved by adapting "options analysis" from financial engineering to the design process. DSP allows for the optimal policy, which cannot be preordained at the beginning of the undertaking, to reveal itself over time as conditions unfold that, even when anticipated, cannot be predicted with certainty.

Engines for Innovation

How, then, can innovation be better understood and accelerated in a controlled way to minimize the debilitating effects of disruption? An "engine for innovation" (EfI), or virtual test bed, is needed to provide a synthetic, non-intrusive environment for experimentation and evaluation of creative ideas and concepts. This synthetic environment, or micro-world, transforms theoretical knowledge into practical applications by catalyzing innovation often found at the seams between disciplines, technologies, and institutions. Thus, an EfI generates technological and managerial initiatives consistent with the organization's vision, "incubates" and rigorously analyzes them within a non-intrusive test bed, then rapidly transitions into actual practice those selected as most promising.

The functional design for an EfI includes three organizational components that comprise core competencies (mission essential tasks) as shown in Figure 2:

- An R&D model and supporting framework to function as a generator, magnet, conduit, clearinghouse, and database for "good ideas"
- 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 on the enterprise
- An implementation component to accelerate the transition of promising concepts into existing organizations, agencies, and companies by providing training, education, technical support, risk reduction and mitigation methods during transformational phases



FFigure Figure 2. An Engine for Innovation

Feedback loops accommodate better understanding as knowledge is generated, and for subsequent model refinement and calibration. These three components do the following:

- Encourage and capture a wide variety of "inventions"
- "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
- Rapidly transition those most promising into actual commercial or governmental practice

An EfI can help guide project planning and execution by providing a "crawl-walk-run" sequence from engineering analysis, then to analytical demonstrations, then to field testing with appropriate feedback loops to accommodate better understanding as knowledge is generated, and for subsequent model refinement and calibration. The purpose of this deliberative, cyclical discovery process is to sustain continuous improvement through experimentation, prototyping, field testing, and rigorous analysis.

Applications and Attributes of Strategic Analytics

In recent years, the application of Strategic Analytics to several Army enterprise challenges has shown these "engines for innovation" can be a valuable organizational mechanism for successfully pursuing transformational strategies. Central to these endeavors was the extensive application of Operations Research, data sciences, and management innovation for improved performance. Although their fundamental natures were vastly different – defense resource planning, sustaining our All-Volunteer Force, and materiel supply chain transformation - they all required an ability to organize, manage, lead, and develop highly talented multi-disciplinary teams (Parlier, 2020). These concepts and methods for Strategic Analytics should now be extended and applied more broadly across many other national security challenges as well.

At its inception 85 years ago, Operations Research was unique in its multi-disciplinary origins which combined both inductive and deductive reasoning. More recently, the convergence of systems thinking, ubiquitous data, and computational advances has made OR an enabling technology for a wide variety of applications. To date, these particular applications of Strategic Analytics not only fully capitalize on the integrative features of OR but also reveal structural similarities, common attributes and characteristics, among these vastly different enterprise challenges. Consequently, they provide a solid foundation for a general theory and framework for Strategic Analytics as a methodology for the design, analysis, and management of socio-technical enterprise systems where improved performance and ultimate success require an understanding of both technical innovation and human behavior.... technological and *social* ingenuity.

Dynamic Strategic Planning enables resilient designs by building flexibility into the project to enable adaptability to changing circumstances that inevitably prevail. This flexibility accommodates inevitable change over time by adapting to a range of future possibilities. This built-in flexibility creates additional value for the system, which in many cases can be quantified. This "optimal" solution will inevitably change over time due to an inability to perfectly forecast future conditions or the consequences of past decisions – often irrevocable - that do not always reveal the results expected. And, no doubt, opportunities provided by adaptation and modification will materialize that require new decisions. This capacity for adaptation enables a resilient enterprise that can adjust gracefully as needed rather than suffer slow-motion or catastrophic failure.

In practical application to the Army's materiel sustainment enterprise, Dynamic Strategic *Logistics* Planning (DSLP) generates an efficient, increasingly effective, yet resilient global military supply chain network. By applying *resilient* design principles, a supply chain operating a large-scale (global), demand-driven ("pull") system under stable and predictable demand can quickly adapt to support localized requirements (e.g., overseas deployment scenario) that may involve considerable uncertainty. From a global enterprise perspective, these resilient concepts emphasize "building in" flexibility. Taking, as input, both the empirical evidence of ongoing operations (real-world results) and new contributions derived from experimental results and operational testing, DSLP then guides enterprise transformation toward strategic supply chain goals for effectiveness, efficiency, and resilience.

"Early Warning", another attribute of Strategic Analytics, provides an ability to anticipate, recognize, understand, and then pre-empt future enterprise system degradation through proactive, preventive management actions. Today, the Internet of Things (IoT) offers another disruptive opportunity for OR to integrate new technologies into enterprise systems. Defined as networks of devices, objects, and people, IoT reflects the convergence of multiple technologies, including: real time analytics, machine learning, sensors, and embedded systems including wireless networks, micro-control systems, and automation. The next wave of the IT revolution is integrating human with machine intelligence by connecting digital and physical worlds to improve performance through greater automation and sensor-based analytics. IoT is also enabling a variety of prognostic early warning systems which capitalize on predictive analytics to anticipate change, then pre-empt system degradation or failure through proactive management interventions in large-scale enterprise systems (see Figure 3). Two such Strategic Analytics applications for defense enterprise systems are: "connecting" Condition-Based Maintenance (CBM+) to military supply chains for a Sustainment Early Warning System; and the Enlisted Early Warning System (EEWS) to support the Army recruiting enterprise for the All-Volunteer Force.

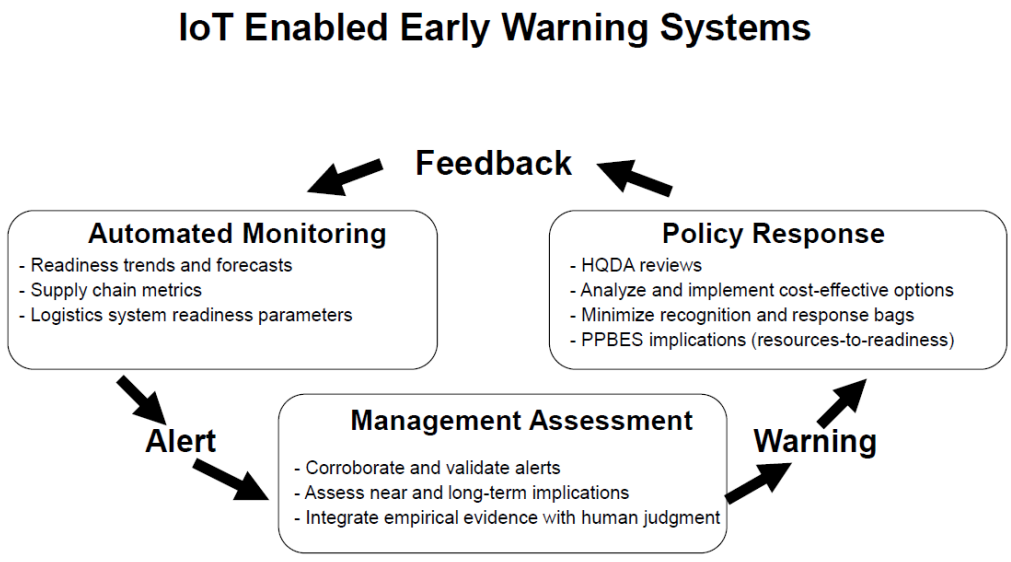


Figure 3. Early Warning for Enterprise Systems

While institutional adaptation requires a culture of innovation, inertia remains a powerful force within bureaucratic organizations. And the pace of technological change is not always compatible with organizational capacity to accommodate change since social stability and cohesion depends more on relationships and habits than on efficient arrangements or policies. Furthermore, our collective human nature tends to procrastinate, postponing necessary changes – especially if they require sacrifice – until crises are upon us. To overcome both bureaucratic inertia and paralysis induced by disruptive chaos, cultures must have sources of innovation they can embrace. Innovation engines (EfIs) accelerate the experimentation process while also minimizing the debilitating effects of disruption. They provide sources for socio-technical innovation to expand organizational capacity for *social ingenuity.* They illuminate likely impacts, quantify cost-effectiveness of alternatives, then guide and accelerate transformative change along cost-effective paths integrating and focusing what otherwise would be disparate initiatives and fragmented research efforts.

EfIs identify implementation issues *before* they are adopted as policy and institutionalized across the enterprise. They accelerate organizational learning while encouraging both technological and social ingenuity as foundations upon which American innovation and national power can be generated and sustained in the future. Of course, "connecting the dots" among key bureaucratic elements is as essential as it is painstaking. These "dots" include senior policy officials responsible for regulatory guidance, program directors who control funding, test and evaluation agencies that rigorously assess plausible alternatives, and of course operators who "own" the problem but are constrained by insufficient authority and in- adequate resources to pursue better options. They all must be "connected" and synchronized to effect innovation.

Another recurring observation from applying Strategic Analytics to several enterprise challenges is that confusion between "ends" (goals to be achieved) and "ways" (how they are achieved) can be uncovered and resolved. One particularly striking example of this confusion, and its persistence, is exemplified by our current military manpower system – the All-Volunteer Force (AVF). In 2018, for the fifth time in five decades, the Army substantially failed its enlisted recruiting mission. Now, in 2022, Army recruiting again appears to be on the precipice of "imminent catastrophic failure," imposing a strategic constraint on the use of American power. We must recognize the AVF, in its current form, has become unsustainable. While our national military manpower system should align with the requirements of defense strategy and our foreign policy objectives, the current AVF is but one of several military manpower systems ("ways") that can be considered to reconcile means with ends. Since the end of World War II, the United States has actually implemented or seriously considered at least five different military recruitment systems. By broadening our perspective to also include domestic challenges to national security, we could improve social cohesion and better develop human capital to provide for the common defense and *ensure domestic tranquility* for ourselves *and our posterity*.

Ideally, whatever military manpower system is selected should constitute both a cultural as well as economic institution in our society. By linking civic virtue to national purpose, cultural cohesion within generations can be improved and bonds of mutual loyalty across generations can be strengthened. It is now an open question whether the AVF can again be sufficiently re-engineered to meet current constraints and endure for perhaps another decade, or whether an alternative system will better serve our Nation. Importantly, it is *not* the existing recruitment system we should venerate, especially if it has been prone to failure and is now failing again. Strategic Analytics can be used to illuminate a better "way" ahead for military recruiting – perhaps uniquely American.

A final, recurring attribute is the remarkable similarities between the emerging "collaborative enterprise" and the original purpose and organizational forms that created OR during the early years of World War II. As noted in the beginning of this essay, the idea for implementing a "system of *teams*" with expertise across multiple scientific and military disciplines represented a unique advancement in military decision-making. Using empirical evidence from ongoing military operations in conjunction with mathematical and statistical models for rapid learning, these early "combat scientists" earned the trust of high-level commanders and government leaders by responsively advising them while operating under extraordinary pressures. We can learn from – we *must* fully capitalize on – the promise of our own heritage.

There is another, broader historical perspective as well. To the extent that Strategic Analytics is adopted, refined, and implemented, we have demonstrated that significant savings can be generated in each of these enterprise applications. These savings can then be internally transferred and reinvested to improve readiness across our operating forces, increase force structure where required, accelerate innovation and modernization to improve future capabilities during a period of growing international unrest, rising competitors, and increasing regional friction.... thereby precluding re-emergence of a "hollow

force". In the past, this condition has been a consequence of the deleterious effects of the US Army's inevitable "boom and bust" cycle caused by precipitous draw downs in force levels during immediate post-war periods. Regrettably, this tragic phenomenon has been an all-too-persistent, yet increasingly dangerous pattern in American history.

FINAL THOUGHTS

For over half a century, from the early 1940s to the late 1990s, Operations Research was *the* enabling competency for defense innovation. Today, however, as numerous recent studies cited earlier illuminate, the current "unprecedentedly weak defense innovation base is a stunning departure from its illustrious history as a daunting bastion of innovation" (Letts and Rodriguez, 2021). With its distinctively rigorous problem-solving paradigm that emphasizes identifying, formulating, and understanding the fundamental nature of any challenge, OR can provide the "glue" to coordinate, orchestrate, and pull defense organizations together to keep them focused, continuously improving and learning while under increasingly greater pressure, precluding chaos and decline during disruptive eras. A powerful byproduct of this approach has been a unique ability to differentiate between *issues* that can - at best - be managed and *problems* that can genuinely be solved.

In conclusion, Operations Research can provide a crucial, indeed unique, source of American power. Our national security enterprise, especially the US Army, should renew and restore Operations Research as a core competency for military innovation, operations analysis, defense strategy, and international security policy. Strategic Analytics should also be widely adopted and used to illuminate better "ways" ahead for defense modernization, encourage imagination, confront conventional wisdom, and better reconcile ends with means in the face of major national security challenges. This analytic framework incorporates imaginative and creative ways to address the many persisting problems and seemingly intractible national and global challenges that confront us. Strategic Analytics can provide *the* crucial innovation enabler for government, academic, and industry leaders to better integrate our intellectual capacities, considerable strategic planning acumen, diverse analytical capabilities, and bring them all to bear on formidable national defense and international security challenges of our time.

"Come my friends,
'tis not too late to seek a newer world…
One equal temper of heroic hearts
…. strong in will
To strive, to seek, to find, and not to yield."

Tennyson, 1842

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