STRATEGY RESEARCH PROJECT

PRESERVING BATTLEFIELD ADAPTABILITY IN A DIGITIZING ARMY

BY

LIEUTENANT COLONEL CLARK K. RAY
United States Army

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by

LTC Clark K. Ray
United States Army

Dr. Williamson Murray
Project Advisor

U.S. Army War College
CARLISLE BARRACKS, PENNSYLVANIA 17013

ABSTRACT

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Especially after periods of substantive technological and doctrinal change, all armies find themselves confronted with the need to adapt the fighting techniques and equipment they developed in peacetime to the realities they face when they encounter a live enemy. The German Army's revamping of their offensive methods during WWI and the U.S. Army's adjustment of its tank destroyer tactics during WWII are two obvious examples. Without taking these lessons into account within the context of what is known from the civilian community about evolving complex software-intensive systems, the U.S. Army could inadvertently field a needlessly 'brittle' digital system of systems that could fail to adapt to the reality and requirements of future battlefields.

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PREFACE

Taking lessons from past wars about the nature of battlefield adaptations and combining it with the current state of knowledge in preserving flexibility in software-intensive systems, this paper attempts to identify concepts and principles to guide the software-based implementation of systems for the Army of 2010 and beyond.

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PRESERVING BATTLEFIELD ADAPTABILITY IN A DIGITIZING ARMY

> "As in so many other instances, the acid test of military effectiveness was whether one could handle not the expected but the unexpected elements thrown up in war."[1]

INTRODUCTION

Change imperatives for the U.S. Army

To fulfill its Constitutional responsibilities in the next century, the U.S. Army has committed itself to a program of digitization as part of its overall modernization strategy and as a principle enabler for "doing more with less." Without adequate funds to field more than a select few new systems (such as the Comanche helicopter and Crusader self-propelled artillery vehicle), the achievement of information dominance through digitization of existing platforms represents a key element in the Army's plans for innovation over the next decade and beyond.[2] Notwithstanding arguments for a radical re-invention of the Army to cope with a future five-dimensional combat environment (post 2010),[3] the stated goals of the army's modernization strategy aim at achieving enhanced *mental* and *physical* agility. Achieving mental agility -- the ability of forces to operate faster than an opponent can decide, act, and react -- demands battlefield systems capable of processing information faster than potential opponents and on soldiers trained in employing and exploiting that superiority.[4]

Of these two goals for army modernization, mental agility represents the more immediate and critical priority. This is not merely due to the fact that investment priorities cannot shift to the attaining of physical agility until a decade or more into the next century.[5] For military effectiveness, it is essential to achieve mental agility before physically agile systems are available. Mental agility is essential for employing physically agile systems, and mid-career and senior leaders need developmental experiences to build the mental agility required by the digitally enhanced systems the Army will field in the next decade. Achieving mental agility will extend digitization from C4RSI (Command, Control, Communications, Computers, Reconnaissance, Surveillance, and Intelligence) into C4/BM (C4 and Battle Management).

How armies enter major conflicts

Although the primary goal of armies after major wars should be to maximize their likely effectiveness after the next major period of innovation, modern history lists more failures at this task than successes. This may be inevitable, since warfare is uncertain and unpredictable. Moreover, no two wars are ever identical. Modeling and experimentation can sometimes -- but do not always -- mitigate some uncertainties regarding the effectiveness of forces developed in peacetime, but these approaches suffer from important limitations.[6] Even 'live fire testing' in the crucible of combat is no guarantee of future effectiveness. Tactics and equipment that are highly effective in one setting may prove catastrophically unsatisfactory in other conflicts.

The U.S. Army should not believe itself immune from the need for rapid change or hold too sanguine a view of the ease with which it can prepare for the next war. Although deliberately employing stinging words, there is the echo of uncomfortable but recognizable truths in the words of a recent Parameters author:

> The reality of America's military past was too often one of institutional mediocrity redeemed by wealth, courage, and blood... Instead of exploring the possibility that new technologies might change the way we organize for war and conflict, we limit ourselves to the selection of technologies that allow us to improve traditional organizations... In this era of American triumph, only two major American institutions continue to resist the future: blue-collar unions and our armed forces. The unions have a better case.[7]

Adaptation differences in future conflicts

Battlefield success demands getting inside of an opponents' *adaptation cycle*. Even General Gamelin noted this aspect of warfare three years before France collapsed in 1940.[8] In the past, military organizations had to change equipment (hardware) as well as doctrine and tactics (wetware - the contents of human minds). In future war, an additional medium -- software -- for wartime adaptation will play a major role. The U.S. Army already is relying heavily on the positive effects it anticipates from advanced information technologies in general and in advances in C4ISR and C4I/BM in particular. In a sustained period of severe budget constraints on procurement and Research and Development (R&D), the Army is relying on digitization -- the soul of which lies in software -- to compensate for other shortfalls as well as to improve its joint (although not necessarily combined) interoperability.[9]

WARTIME ADAPTATION

Innovation, Adaptation, and Improvisation

All armies which seek to fulfill their duty to their nation must deal with change during periods of peace and war. The need for change may occur from failures, such as the recognition during WWII that American doctrine on the role of tanks and tank destroyers was deeply flawed.[10] It may also occur when military forces find themselves assigned strategic objectives for which they had not prepared in peacetime. "…An age-old problem is the employment of military forces to achieve objectives for which they are largely unsuited."[11] While there has been much talk of the 'Revolution in Military Affairs' (RMA) and the prospects for drastic changes in the conduct of future wars, the limitations, described by Clausewitz, on the ability of human intellect to comprehend war will remain a basic fact of war.[12] The "…fundamental aspects of the human condition and unavoidable unpredictabilities that lie at the very core of combat processes"[13] will continue to drive the need for military forces to successfully change.

Change may take the form of *innovation* -- complex and long duration activities such as converting World War I armies into mechanized forces. Change may be *improvisation* and *adaptation* -- the frequent responses to battlefield challenges by soldiers in every era, such as the simultaneous but independent invention by Lieutenant Charles Green of the 29th US Division and Sergeant Curtis Culin of the US 2nd Armored Division of ways to utilize German defense materials to construct attachments that enabled Sherman tanks to cut through the bocage hedgerows of northern France.[14] Ideally improvisations would never be necessary. Nevertheless, specific improvisations may have army-wide applicability to remedy defects in prewar structures and procedures and can be incorporated across the service as a wartime expedient.[15] It is likely that the middle ground -- adaptation -- between improvisation and innovation will be where combat will most severely test the software constructed to support 21st century military operations. In general innovation is too complex, too unpredictable, and too slow to be the predominant form of change in wartime; in most cases adaptation is the best real world solution to intractable wartime problems.[16] Adaptation is also one of the most essential requirements of a successful wartime army. The recovery of military effectiveness by the Israeli armed forces during their 1973 war underlines this point.[17]

Errors in innovation

Failure to innovate is perhaps the most obvious 'error in innovation' that an armed service can commit. It is unlikely that a service upon which its nation expends significant resources will simply refuse innovations that its potential enemies and allies adopt. More likely is that an innovation, if it fails to conform to preconceived ideas and beliefs of the service, will be co-opted into existing doctrinal structures or starved of resources. Naval air arms did not fare well in the interwar period in nations which established independent air services. Similarly, the ground attack mission for tactical airpower languished where the doctrines of the established air forces (whether or not they were separate services) focused on a vision of strategic bombing in isolation from the opportunities offered by a wider application of air power.[18] Not for trivial reasons does the US Army operate more aircraft (principally helicopters) in its aviation units than does the US Air Force, or does the army of the US Navy (the Marine Corps) have its own jealously guarded air force.

The mere fact that an armed service has started down the road to innovation ahead of its potential competitors is no guarantee it will maintain its lead. Fifteen years passed between the arrival of the first practical submarine and its integration into a general scheme of maritime war (driven finally by World War I).[19] In theoretical work and actual field trials, the British Army of the late 1920's was far ahead of all other armies in developing mechanized ground forces. Its determination that every armored fighting vehicle needed a radio[20] was a key doctrinal innovation that only the German armored forces had fully internalized by the start of World War II. Yet by the start of that war, the British Army's doctrine, equipment, and performance in armored combat was and remained seriously behind those of German and the USSR, bordering on combat ineffectiveness. The British were not to regain parity with German, Soviet, or even American armored forces throughout the duration of the war. Military forces can not easily make up for the squandering of an early lead in innovation.

Errors in adaptation

Armies have shown the capability to attempt large-scale adaptations during the wars of the 20th century, but the success rate of such efforts have fallen far short of 100 percent. The deficiencies in the British Army's attempts to prepare for the German spring offensive of 1918, even when a template for change was available (in this case, German defensive doctrine) suggests the pitfalls that await military organizations not prepared to accept the logic of change and its inherent consequences.[21] Perhaps the greatest error in adaptation during wartime is the refusal to recognize the need to adapt. Unfortunately, the tendency of twentieth century armed forces to resist change in their peacetime assumptions and perceptions in response to war seems relatively commonplace.[22] While military leaders often lament that decision makers are late in making decisions at the strategic level, they also tend to miss their own *need* to adapt. Thus, there is a premium on developing an army with *optimized abilities* to adapt.

Inflexibility - the inability to adapt

Flexibility is an essential element of military effectiveness. A three volume study, Military Effectiveness, by Allan Millett and Williamson Murray, has characterized 'military effectiveness' in significant depth. The authors identify indicators of military effectiveness in the political, strategic, operational, and tactical realms. Table 1 provides a subset of the characteristics in their taxonomy which directly applies to adaptability in software for a digital army, along with a potential categorization of the relative importance of software for adaptability.

ACTIVITY LEVEL	EFFECTIVENESS CHARACTERISTIC	RELEVENCE TO SOFTWARE ADAPTABILITY
Political	Budget sufficient to meet needs	moderate
Strategic	Goals consistent with force structure	High
Strategic	Strengths placed against adversary's weaknesses	High
Operational	Integrated methods to combine combat arms	High
Operational	Concepts consistent with available technology	High
Operational	Intellectual and physical mobility and flexibility	High
Operational	Support integrated with operational practices	Moderate
Tactical	Tactics consistent with operational capabilities	Moderate
Tactical	Tactical system emphasizes integration of all arms	Moderate
Tactical	Tactical systems consistent with support capabilities	Moderate
Tactical	Strengths placed against adversary's weaknesses	Moderate

Table 1

ADAPTABLE SOFTWARE

Although current and future automated systems consist of both hardware and software, the constraints on employing these technologies fall away much more rapidly in the realm of hardware than in software. "Over the next decade, computer speeds will rise about a hundredfold, while bandwidth increases a thousandfold or more. …The law of the telecosm holds that if you take any number (n) computers and link them in networks, you get n squared performance and value."[23] Confounding earlier predictions of its 'inevitable' demise, Figure 1 displays the dramatic and relatively constant forward march of computing

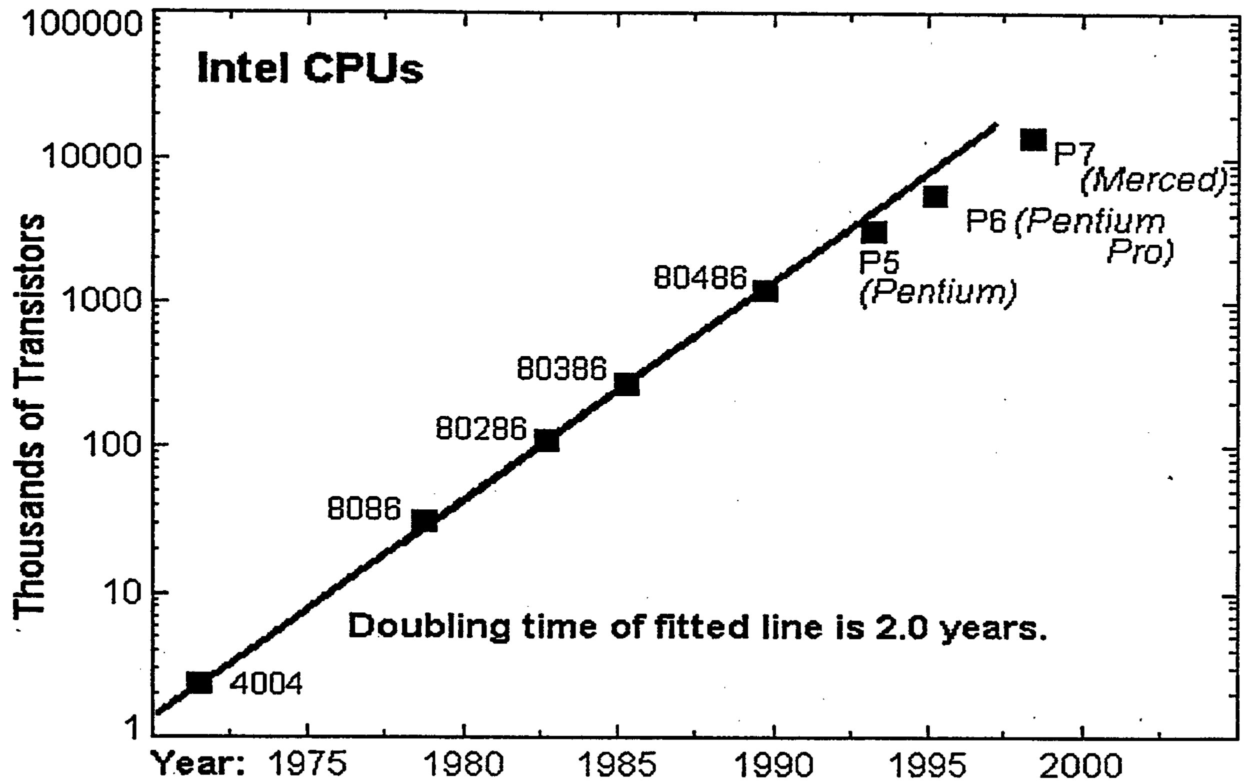

Figure 1

capacity as suggested by Moore's law.[24] Almost daily, news of technology developments gives testimony that the pace of innovation in hardware shows no sign of imminent collapse.[25]

Bill Gates predicted in the October 1994 issue of *PC Magazine* that within a decade, bandwidth for the individual user would be essentially unlimited.[26] The major competitors have resolved the final barriers to adopting international standards in wireless communications.[27] This agreement will result in a revolution in inexpensive, easy to operate technologies by the commercial sector and provide pervasive wireless connectivity. "…[T]he world will be predominantly wireless in the future."[28]

"By 2018, the world will be able to use serial space-based phone systems … and at least one high-bandwidth Internet-based system…"[29] DARPA is currently sponsoring research to add geographic routing to existing Internet protocols,[30] which will greatly facilitate addressing and reconfiguring the networks connecting mobile forces and platforms.

There are concerns regarding the risks posed in relying on systems other than ground-based near Line-Of-Sight (LOS) nodes for communications, since satellites are vulnerable to forces of nature (such as sunspots) and deliberate degradation or destruction (by anti-satellite systems or high altitude ionizing nuclear detonations). Over the long term, these risks will be mitigated because the criticality of satellite systems to the world economy will enforce investments in survivability and redundancy, and because airborne platforms (manned or unmanned) can supplement or supplant the need for satellites; such capabilities are already being demonstrated.[31] As developments in the commercial sector drive the cost of processing and bandwidth to very low marginal cost levels, the remaining challenges to construction of an adaptable digital nervous system for the army of the coming century lie in software.

Failures and successes from software development history

The fragile nature of huge monoliths

The persistent high failure rates of large (hundreds of millions of dollars) commercial and governmental software development projects underlines the difficulty in constructing adaptable software artifacts. As individuals, Americans have a growing sense of the pervasive degree to which much computer software is non-adaptable. The media has repeatedly reported on the glaring software Year 2000 (Y2K) problem. Another indicator of the high risk in attempts to construct huge, self-contained software systems from fixed specifications is the industry (and governmental) experiential rule of thumb that approximately one-third of such systems will be undisguisable failures, one-third will be delivered but never add significant value to using organizations, and one-third will provide some approximation of intended value, although perhaps after late delivery and expensive re-working. The recently announced problems in the new multi-billion dollar Federal Aviation Administration's 'Stars' air traffic control system[32] (itself a follow-on to another multi-billion dollar project earlier this decade which was a complete failure) indicate the rule has lost none of its harsh reality.

The spiral development model first articulated and advocated by Barry Boehm provides an alternative to the derived-fromstatic-requirements software monolith. This model calls for the iterative development and fielding of systems. It starts with (relatively) simple adjustable requirements, based on user experience, and provided for risk analysis and mitigation as part of the development cycle. To some degree, DoD's procurement practices have incorporated this concept in parallel with attempts to allow private sector contractors flexibility in meeting a set of requirements without the burden of meeting excruciatingly detailed specifications on sub-components, materials, procedures, and other minutia. Nevertheless, problems remain in providing effective incentives to promote software re-use, incorporating evolving changes in specifications, and the willingness to terminate projects that are already on the road to failure.

The Unix idea: do individual small things well

An example of a large and complex software artifact that has evolved over time without becoming brittle and non-adaptive is the Unix operating system in its various modern forms (such as Linux). The success of Unix stands in stark contrast to monolithic attempts that targeted the same operating system role such as Multics. From its beginning, a key idea in the development and evolution of the Unix operating system was to have it consist of small components that each did a specific, clearly understood task well.[33] By building on a diverse and robust resource base of components, system developers and operators could provide new functionality in relatively short order by combining the proven components in new ways.

Characteristics of durable software

Despite many individual and interpersonal aspects of software development, during the past four decades software engineers have identified several important quantifiable characteristics. In the 1960's Frederick Brooks first observed that beyond a critical limit, adding manpower to a software project that was late makes it later. In terms of lines of tested and accepted source code produced per month per programmer, software productivity generally declines as the size, requirements, or safety-criticality of the system increases.[34] Careful attention can improve the processes for creating software from specific requirements,[35] but ultimately there are no combinations of software tools, process improvements, new computing paradigms, or other mechanisms that will provide the 'silver bullet' to solve the inherent problems in developing complex software systems.[36]

Engineers can adapt durable software not only to remedy defects but to adjust to changes in the underlying human and material processes. Development methods which have the specific aim of promoting the reuse of software in different systems or in future versions of a given system provide many advantages.

Costs are lower, quality improves, prototyping and implementation times decline, and the ability to react to changes in user requirements improves.[37] For software to be genuinely reusable, it must reflect well-defined modular design principles and avoid intricate interconnections with software not logically part of the reusable component.

Attractive characteristics of Open Source software

'Open Source' software is software for which the source code is freely available for examination, modification, derivation, and redistribution without charge. Open source software is typically licensed (at no charge) to ensure that software derived from an open source product remains open source.[38] In the 1990's, major open source software artifacts such as Unix variants, the Apache Web server, key Internet infrastructure programs such as Sendmail, Domain Name System servers, and the Netscape browser have arrived as major factors on the software scene. Developers contributing to the Unix-based Linux operating system have seen it become widely adopted under the open source concept. Experts project its commercial shipments to "grow faster than those of all other client or server operating environments through 2003".[39] The idea of free software with open source code has provided a new development (and economic) model for creating and evolving large software artifacts that indicates a route to overcome the overcome the tyranny of Brooks' Law.[40] Open source software development does not offer a 'silver bullet' to remove inherent complexity, but it does offer a way to dramatically scale up the number of programmers and designers who can productively work on a large project at the same time.

ADAPTATION NEEDS DURING FUTURE CONFLICTS

> Current force structures and information architectures extrapolated to the future may not suffice to meet successfully the conditions of future battle. Automation and systems architectures capable of disseminating information to widely dispersed and dissimilar units and integrating their actions will be key.[41]

It is inevitable that regardless of how the US Army has innovated and evolved prior to its next major conflict, adaptation during that conflict will be absolutely necessary for effectiveness. Not unlike to situation of the British Army between WWI and WWII, there is no clear view regarding what the nature of the army's involvement in the next major conflict might be, a factor which puts the army at substantial disadvantage in preparing for war.[42] Consequently, it is unlikely that the army's peacetime innovation will be entirely suitable for the challenges potential opponents will raise. History indicates that the army's peacetime structure and culture will have a substantial impact on the degree to which its officers and NCOs will adapt rapidly to wartime conditions.

"An adaptive military must have agile warfighters … Institutions matter because they form the context into which agile warfighters are recruited, and they can enhance or impede the ability of warfighters to adjust to change."[43] When the imperatives of war overcome peacetime barriers, the ability to adapt technologies and their uses, even in the 'merely tactical' realm, can be of decisive importance. "… High tech superiority bestows clear tactical advantages [that] tend to assume strategic importance indirectly as enabling factors for operational and strategic advantage."[44]

Changes in existing modules

Probably the easiest adaptations required of software in war are well-defined changes to specific modules. A low-level example of this concept is the 1553B Data Bus found in upgraded versions of the M1 Abrams tank. A standard bus allows developers to be attach, detach, upgrade, reconfigure, or add subsystems without disturbing other subsystems (modules) of the total system interconnected by the bus.[45] A current operational example occurred during operations supporting Desert Storm. In that conflict Army and Marine Corps forces discovered that their unit-level circuit switch communications were not fully interoperable; software modifications resolved the problems.[46]

Rapid releases of software updates.

As software becomes crucial to affecting changes in force structure and doctrine, the incorporation of new equipment, and the exploitation of new ideas, software updates will continually extend force capabilities. It will not be possible to align software releases as annual or even semi-annual events. Already major commercial enterprises such as Wal-Mart are deploying new versions of critical software systems, such as accounting and inventory, every three months.[47]

Re-configuration of 'systems of systems'

At the other extreme is the rearrangement of the software making up the digital underpinnings of a 'system of systems',[48] or systems architecture. "...Our ability to exploit information technologies to create systems architectures -- the integration of forces and platforms -- is likely to be a future core capability."[49] With information technologies taking the leading role in military capabilities, the same shocks that these technologies bring to the commercial world will have an impact on the armed forces. Discontinuous change characterizes the response to developments in information technologies, with generational cycles as short as eighteen months.[50] Such discontinuous change requires an ability to reconfigure subsystems in the force, replace or remove existing subsystems, and add new ones.[51] Vested interests in the organization are likely to act as brakes and barriers to change. Those responsible for change must recognize and mitigate (or eliminate) such opposition. "Technology-driven revolutions in military affairs entail the reorganization of forces and doctrine around those new technologies."[52]

An example: CONUS-based TOCs

As a hypothetical requirement to adapt software to support radical reorganization in the information flows of a digitized army in combat, consider the prospect of implementing a wartime decision to remotely locate battalion, brigade, and perhaps higher level staffs to reduce logistical burdens, increase agility, and enhance decision making. Removing traditional command and control support structures from the theater of operations conforms to the "Force Characteristics of Small Logistics Footprint and Mobility" outlined in the "1997 Report of the National Defense Panel for Future Conventional Forces" and conforms to its concept of concentrating effects instead of forces.[53] Although foreseeable advances in communications and information technologies will make the execution of such a decision possible, it would still require large-scale and rapid reconfiguration of the information 'system of systems', followed by ongoing adjustments based on user experiences and feedback. Radical changes might be difficult to envision and execute during peacetime due to the number of organizational stakeholders who would perceive themselves as losers, but such change might become a sudden imperative during war.

RECOMMENDATIONS

> The U.S. Military today has a commanding advantage in military capability. But in a period of great geopolitical and military—technical change and uncertainty, it is far from clear that this advantage will be sustained over the long term… A successful transformation strategy must provide for…effecting meaningful and appropriate change in operational concepts, force structures, military systems, and budgets.[54]

It is instructive to review a portion of a list C4 system weaknesses compiled in the wake of the Gulf War:[55]

1. Compartmentation: many separate subsystems had severe difficulty in "talking" to each other.
2. Hierarchical non-redundant centers and nodes: sometimes the system could not effectively recover from the loss of a major facility at the top level or reconnect around a missing node.
3. Rigidity: Lack of doctrine or training in rapidly adapting C4I/BM systems to changes in the nature of the battle or to provide new functionality.
4. Lack of automation, inadequate software, incompatible systems, over-reliance on voice or low-data-rate communication.

Although these were characteristics of the Iraqi C4 system, it is unsettling to note the ease with which one might conclude that they represented a description of the army's current battlefield communication and automation systems of today, much less the Gulf War. By whatever means and structures the army has pursued C4I/BM advances in the past ten to twenty years, the overall degree of success leaves much to be desired.

The need for adaptability in wartime is serious business, and one must not underestimate the ability of military organizations to resist change.

> Military organizations often take mistaken conceptions into war. This should not be surprising. *What is surprising* is the tenacity with which they have often maintained these mistaken conceptions in the face of overwhelming, contrary evidence and at the cost of large numbers of young men called upon to fight their battles.[56]

Constrained appetites

The essence of avoiding the problems inherent in gargantuan software monoliths lies in proper design of the architecture and choices of modules. This permits management of inter-module coupling and intra-module cohesion through exploitation of information hiding. Successfully employing the principles of software reuse requires carefully modularized designs and implementations. However, software engineers best achieve information hiding when appetites for maximum performance, creeping featurism, and special purpose intra-system connections are minimized. "An adaptive system of systems would look to…bottom-up systems integration for robustness … it would probably be less efficient at any one task…but it would span a wider range of operational contingencies … Adaptiveness is not free…"[57]

On a different level, 'constrained appetites' is an appropriate guide for avoiding large, complex, institutional solutions for the requirements of digital battlefield communication when there are or promise to be simple, distributed, and embedded technological alternatives in the form of internetworked wireless LOS and non-LOS solutions. An innovation strategy that embeds communications in the same pervasive, low-overhead manner as providing electric power or water would be far more responsive than communications during the Gulf War:

> The Gulf War may be a warning that the US also needs to fundamentally rethink its C4I/BM architecture in light of the need to use low-cost satellites and system components and limit the need for communication, rather than continuing to provide increased equipment and capability. In practice, the answer to "How much is enough?" cannot always be "More!" It also cannot be improvisation, where the alternative to "more" is often "failure." The Gulf War is also a lesson [in] simplicity, independence of operations, and the proper delegation of command authority...[58]

The role of standards

Undoubtedly standards are well-loved, as evidenced by the fact that everyone wants to have their own proprietary ones. Nevertheless, employment (or, if necessary, development) of appropriate standards is essential for successfully managing the development and evolution of software-intensive systems.[59] The Army's and DoD's spotty record of enforcing adherence to the commercial and international standards it selects underlines the need for improvement in this area.

Recognizing transition periods

Comments from officers and enlisted personnel who have served or are currently serving in the 4th Infantry Division, the Army's first 'digital' division, suggest valid concerns about equipment, training, and especially personnel problems. The next few years of this process of innovation promise to be just as traumatic for those involved. The U.S. Army as whole is operating in an environment of high operational tempo and seriously constrained resources, quite similar to that which confronted the British Army during the interwar period of the 1920's and 1930's. It is, however, important to realize that the proper outcome of digital innovation should and must be a force where thee innovations have greatly reduced the current complexity and human demands of the enabling technologies. Not only must the army adopt the appropriate transitional (i.e., temporary) measures to mitigate the current evolutionary pains of digitizing the force, but it must plan for the outcome of this evolution to reduce the need to continue such measures.

Planning the end of the Signal Corps

One way to ensure that software structures support the armed forces in future conflicts and remain adequately adaptable is to uncouple as much of the architecture and implementation as possible from organizational structures and stakeholders (other than the end users - the combat arms). In direct terms, this means planning for systems that do not require a substantial separate branch to maintain them in the field. As a practical matter, this means the army should plan for a force where there is no requirement for the Signal Corps as a separate branch.

Sun Tzu cautioned against allowing those authorities not steeped in the knowledge of war to exercise undue influence over military affairs.[60] It is simply not reasonable to expect an institution to internalize new competencies which it does not recognize as part of its existing identity. The disenchantment felt by many Army automators over the past decade since the Signal Corps absorbed most of the army's computing, automation, and digital networking functions is therefore not surprising. It is, however, clear evidence that it is not reasonable to expect the Signal Corps to embrace a digital future that diminishes its own role. This reluctance is consistent with the historical record of the failure of separate air services to embrace the needs of naval aviation or of cavalry and infantry branches to embrace the potential of mechanized warfare during the interwar period.[61]

The argument to plan for the disestablishment of the Signal Corps is not one in favor of a technically illiterate army. Hans von Seeckt, arguably the founder of the German Army that dominated the battlefields of Europe for the first half of WWII, recognized the importance of officers being technically knowledgeable in order to direct the employment of modern weapons.[62] However, that is not an argument for needlessly maintaining structures which require large cadres of technical specialists for purposes (such as communication) which do not directly apply to "...act[s] of force to compel our enemy to do our will."[63] The entire issue of officer roles is inextricably bound up with the army promotion system and the perceived needs and values of the Signal Corps as a branch contrasted with the roles and backgrounds necessary for officers who will be future digitization innovators. "Peacetime innovation has been possible when senior military officers...have acted to create a new promotion pathway for junior officers practicing a new way of war."[64] As long as the prerequisites for success as a Signal Corps officer remain within a narrowly defined communications domain instead of the broader digitized battlefield system, imaginative innovation in digitization is unlikely.

While planning for the disestablishment of a branch may seem radical, it is in fact quite reasonable in light of the desired end-state of the digitization process and projections of likely trends. Few at the beginning of the interwar period clearly foresaw the abolition of horse cavalry[65] or the end of coastal artillery. Few today would argue for the need for a Water Purification branch or an Electric Power Generation branch. Yet provision of water and electric power are fundamental to modern military operations. The need to adapt automated systems rapidly in a wartime environment demands the reduction of organizational elements within the Army with significant interests in the details and resourcing of the status quo. Support for existing methods and force structures "...are almost impervious to countervailing evidence when those beliefs bear on institutional autonomy or existence, however justified those ends might be."[66]

Just as senior officers in the infantry or cavalry who lacked detailed knowledge of mechanized warfare often made guiding decisions concerning the development and employment of armor during the interwar period preceding World War II,[67] senior Signal Corps officers charged with many of the developments of Army automation lack significant education or experience in other than point-to-point or voice communications. They lack thorough understanding of emerging digital technologies unless they have taken special pains to educate themselves in such matters. As was the case for early mechanization where innovators came from traditional branches, such senior leaders exist but are notable as exceptions. Their claim to a background in a closely related technical field provides no promise they will provide adequate guidance in peacetime or adaptation in war, especially if the protection of pre-existing concepts and force structures remains paramount. The failure to prepare long-range fighters, or even to recognize their need or feasibility, escaped US and British senior air leaders until the last two years of World War II.[68]

Considering and then deciding to implement a plan to remove a branch of the army, even in the face of obvious technological developments, is almost certain to provoke strong reactions not always grounded in logic. As reflected in the experience of the British Army in WWI, what was

> striking about senior...officers...was their ready acceptance of new [technologies], but their emotional difficulty in coming to mental grips with the...changes implied by the new or improved technology...[T]he transfer from one paradigm to another is an emotional shift and not strictly a mental change...[T]he emotional attachment to [existing] ideas and army structure was simply too strong for most senior officers...not even [when confronted] by the harsh lessons of the war.[69]

Attempting to pursue digitization of the army while preserving unchanged some of its most fundamental structures is simply not reasonable. Information technology is more than an enabler for change; fundamental change now originates with this technology.[70]

Summary

Some of the arguments above are conventional and unsurprising, but some are radical and perhaps even heretical. However, radical change is a basic requirement in the pursuit of effective innovation in response to revolutionary developments in the external (non-military) environment. The army needs to accept the need for difficult changes before it can make a compelling case for more resources, redefined missions, or other assistance from the nation and its political leaders.

Having envisioned the demands and guiding principles of the future battlefield in such documents as Army Vision 2010,[71] the army must accept the need for drastic changes to fulfill that future. "*An army that adopts tactical doctrine that it cannot apply will greatly multiply its misfortune.*"[72] If the army can engage in painful and professionally emotional change, it can turn some aspects of its currently resource-poor, mission-rich environment to advantage.

The German Army of World War I stands as a resolute example of successful change (at least in the tactical and operational realms). Arguably it was this same army that "…was compelled toward innovation and army reform due to a lack of manpower and resources".[73] "More than anything else, the military organization ought to strive to get its own house in order before criticizing outside factors" or "…it is unlikely to maintain its military effectiveness for long…"[74]

WORD COUNT = 5733.

ENDNOTES

[1] Allan R. Millett and Williamson Murray, Military Effectiveness, Volume I (Boston: Allen & Unwin, 1988), 333.

[2] Department of the Army, Research, Development and Acquisition Master Plan 1999 (Draft), (Washington, D.C.: U.S. Department of the Army, 1988), 1.

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[11] Millett and Murray, Military Effectiveness, Volume I, 18.

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[16] Williamson Murray and Allan R. Millett, Military Innovation in the Interwar Period (Cambridge: Cambridge University Press, 1996), 377.

[17] Millett and Murray, Military Effectiveness, Volume I, 14.

[18] Murray and Millett, Military Innovation in the Interwar Period, 188. "In the final analysis, close support aviation suffered because of a conscious neglect on the part of the respective air force leaderships."

[19] Theodore Ropp, The Development of a Modern Navy: French Naval Policy, 1871-1904, (Harvard University, 1937), 542.

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[25] New York Times, "A Milestone on the Path to Ultrafast Computers," 6 April 1999; available from <http://www.nytimes.com/library/national/science/040699sci-computer-memory.html>; Internet; accessed 6 April 1999. "A group of I.B.M. researchers said last week that they had designed the building blocks of a new kind of computer memory that could fundamentally alter computer design early in the next century. Chips based on this new technology, known as tunneling magnetic junction random access memory, or tmj-ram for short, would be ultrafast, consume very little power and retain stored data when a computer was shut down."

[26] This is not to say that bandwidth would become infinite. Absent radical and socially wrenching changes in biotechnology, there is a limit to the rate at which the sensory systems (sight, hearing, touch, taste, smell, motion perception, etc.) of a human being can absorb information. This rate probably lies within the capabilities of today's T-1 and T-3 communication line bandwidths (approximately 1.5 and 45 million bits per second). Information processing tasks requested by a given user which exceed these bandwidths can be performed at a remote location and the results transmitted to the user within the bandwidth limits listed above. In such an environment, communications costs per user would probably take the form of a relatively low fixed cost with a marginal cost approaching zero (such as typical local telephone service today).

[27] CNN, "Telecom chiefs on same wavelength," 5 April 1999; available from <http://www.cnn.com/TECH/ptech/9903/30/telecom.lat/>; Internet; accessed 5 April 1999. "The wireless industry … breathed a collective sigh of relief last week when phone rivals Ericsson of Sweden and San Diego-based Qualcomm Inc. announced that they had resolved their years-long technology disputes. Their multifaceted agreement headed off a

patent infringement … and it clears the way for the selection of a single worldwide standard for wireless technology."

[28] Sven-Christer Nilsson, President and Chief Executive of Ericsson of Sweden, quoted in CNN, "Telecom chiefs on same wavelength", 5 April 1999; available from <http://www.cnn.com/TECH/ptech/9903/30/telecom.lat/>; Internet; accessed 5 April 1999.

[29] Institute for National Strategic Studies, 1998 Strategic Assessment: Engaging Power for Peace, (Washington, D.C.: National Defense University, 1998), 251.

[30] Tomasz Imielinski and Julio C. Navas, "GPS-Based Geographic Addressing, Routing, and Resource Discovery," Communications of the ACM Vol. 42, No. 4 (April 1999): 92.

[31] Martin Kasindorf, "Marines Test For High-Tech Tactical Edge," 15 April 1999, USA Today, 3. "Troops used Ground Positioning Satellite (GPS) equipment, the current technology, to tell superiors their location. But wireless networks, using airplanes or drones, will "get away from the dependence on satellites, because if the satellites go down, you're blind," Thiffault [an information officer at Camp Pendleton] says."

[32] CNN, "Report: New FAA Radar not Up to Speed," 7 April 1999; available from <http://www.cnn.com/TRAVEL/NEWS/9904/07/faa.radar.ap/>; Internet; accessed 7 April 1999. "A new $1 billion Federal Aviation Administration computer system is proving to be so slow in tests that it takes at least twice as long as the equipment it is supposed to replace...[an internal report] quoted FAA officials as saying that, until fixed, the new system is unsuitable for use at the nation's busiest airports, where it is needed most. The first elements of the system were to be installed at Washington's Reagan National Airport by March 31, but the FAA announced in February it would not meet that deadline. No new date has been set… Each process has been plagued by costly delays. The Stars project… is expected to cost $2.2 billion."

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[34] Barry W. Boehm, Software Engineering Economics (Englewood Cliffs, JR: Prentice-Hall, 1981).

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[36] Frederick P. Brooks, The Mythical Man-Month (Reading, MA: Addison-Wesley, 1995).

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[38] Tim O'Reilly, "Lessons from Open-Source Software Development," Communications of the ACM, Volume 42 Number 4 (April 1999), 34.

[39] CNN, "Linux projected to outpace all contenders through 2003," 5 April 1999; available from <http://www.cnn.com/TECH/computing/9904/02/linuxgrow.ent.idg/>; Internet; accessed 5 April 1999. "IDC [International Data Corporation] estimates that Linux commercial shipments will increase at a compound annual growth rate (CAGR) of 25 percent from 1999 through 2003, compared with a 10 percent CAGR for all other client operating environments combined, and a 12 percent CAGR for all other server operating environments combined."

[40] A good summary of how this new method of producing software works and how it differs from traditional methods can be found at <www.edventure.com/release1/1198.html>.

[41] National Defense Panel, Transforming Defense: National Security in the 21st Century, (Arlington, VA: National Defense Panel, December 1997), iii.

[42] Murray and Millett, Military Innovation in the Interwar Period, 12.

[43] Institute for National Strategic Studies, 1998 Strategic Assessment: Engaging Power for Peace, 231.

[44] John F. Guilmartin, Jr., "Technology and Asymmetrics in Modern Warfare," in Challenging the United States Symmetrically and Asmmetrically: Can America be Defeated?, ed. Colonel (retired) Lloyd J. Matthews (Carlisle Barracks, PA: Strategic Studies Institute, July 1998), 34.

[45] Robert S. Cameron, "Pushing the Envelope of Battlefield Superiority," Armor (November-December 1998): 11.

[46] Anthony H. Cordesman and Abraham R. Wagner, The Lessons of Modern War Volume IV: The Gulf War, (Boulder, Colorado: Westview Press, 1996), 260.

[47] Larry Downes and Chunka Mui, Unleashing the Killer App (Boston: Harvard Business School Press, 1998), 206.

[48] Institute for National Strategic Studies, 1998 Strategic Assessment: Engaging Power for Peace, 237. "Over the last few years, some observers (such as Admiral Owens, former Vice Chairman of the Joint Chiefs of Staff) have argued that an emerging 'system of systems' would link DoD sensors and weapons systems, enabling networks, databases, and what is often called the Revolution in Military Affairs (RMA). An ability to mix and match components within a broad defense architecture could contribute greatly to adaptiveness."

[49] Ibid.

[50] National Defense Panel, Transforming Defense: National Security in the 21st Century, 7-8.

[51] Ibid., 41.

[52] Ryan Henry and C. Edward Peartree, "Military Theory and Information Warfare," Parameters Vol. XXVIII, No. 3 (Autumn 1998): 134.

[53] Ibid., 45.

[54] National Defense Panel, Transforming Defense: National Security in the 21st Century, 70.

[55] Anthony H. Cordesman and Abraham R. Wagner, The Lessons of Modern War Volume IV: The Gulf War, 268.

[56] Murray and Millett, Military Innovation in the Interwar Period, 139.

[57] Institute for National Strategic Studies, 1998 Strategic Assessment: Engaging Power for Peace, 241—242.

[58] Anthony H. Cordesman and Abraham R. Wagner, The Lessons of Modern War Volume IV: The Gulf War, 264.

[59] Marciniak and Reifer, Software Acquisition Management, 33.

[60] Samuel B. Griffith, Sun Tzu: The Art of War (London: Oxford University Press, 1963), 81.

[61] Allan R. Millett and Williamson Murray, Military Effectiveness, Volume II (Boston: Allen & Unwin, 1988).

[62] James S. Corum, The Roots of Blitzkrieg (Lawrence, Kansas: University Press of Kansas, 1992), 33.

[63] Carl von Clausewitz, On War, trans. Michael Howard and Peter Paret (Princeton, NJ: Princeton University Press, 1976), 75.

[64] Stephen Rosen, Winning the Next War, (Cornell University Press, 1994), 251; quoted in Williamson Murray and Allan R. Millett, Military Innovation in the Interwar Period (Cambridge: Cambridge University Press, 1996), 381.

[65] Harold R. Winton, To Change an Army, (Lawrence, Kansas: University Press of Kansas, 1988), 29.

[66] Murray and Millett, Military Innovation in the Interwar Period, 143.

[67] Murray and Millett, Military Innovation in the Interwar Period, 45. Regarding successful innovation in armored warfare: "…the British, who possessed the time…never displayed the talent…They remained prisoners of their compartmentalized conceptions of warfare that characterized their branches. They remained gunners and infantrymen to the end, while the [Chief of the Imperial General Staff]…insured that no one with experience in armored warfare ascended the ladder to command of an armored division in combat."

[68] Murray and Millett, Military Innovation in the Interwar Period, 19.

[69] Tim Travers, The Killing Ground (London: Unwin Hyman, 1987), 253.

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[71] Army Link News, "Army Releases Army Vision 2010," 20 November 1996; available from <http://www.dtic.mil/armylink/news/Nov1996/a199611152010.html>; Internet; accessed 5 April 1999.

[72] Timothy T. Lupfer, The Dynamics of Doctrine (Fort Leavenworth, Kansas: Combat Studies Institutes, 1981), 56.

[73] Tim Travers, The Killing Ground, 261.

[74] Millett and Murray, Military Effectiveness, Volume I, 349.

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