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SHOTGUNS AND SHARPSHOOTERS: COMMAND, CONTROL, AND THE SEARCH FOR CERTAINTY IN THE U.S. WEAPONS ACQUISITION PROCESS

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FOREWORD

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Through this series of working papers, the Institute of Governmental Studies, Berkeley, provides a channel through which scholars at work on problems of public organization may present their thoughts in a convenient form and without too much delay. We envision this series as a modest undertaking, but we hope that "Studies in Public Organization" will make some contributions toward an understanding of the properties that describe the variety of public organizational systems that exist throughout the world. We want also to note that no single formula will dominate; the series will contain papers that are theoretical, methodological, comparative, or historical. It is open to faculty and student contribution alike, not restricted to this campus, and its objective is to publish papers that engage important problems and present interesting ideas.

Committee on the Study of Public Organization
IGS, University of California, Berkeley
The Editors

Introduction

In recent years, the steadily increasing cost and development time for the latest state-of-the-art technology has caused many to question whether it would not be wiser on both budgetary *and* military effectiveness grounds for the U.S. to settle for somewhat less than the most sophisticated weapons and forces it could theoretically achieve.[1] It is "common knowledge" that the Soviet Union has and will retain a relative advantage in overall numbers of weapons as well as troops, and that the U.S. must exploit its own comparative advantage in technology to maintain the balance.[2] The primary question in what has now come to be characterized as the "defense reform debate" is not whether the U.S. should seek to apply its superior technology, but which technologies should be adapted, how, and to what ends.

This debate cannot be posed merely as an argument between "quantity" and "quality", between buying fewer, more sophisticated and expensive weapons and larger numbers of less sophisticated and less costly ones. To some extent that "tradeoff" is not a matter of choice, but inherent in the asymmetries of the geo-political positions and strategies of the U.S. and the Soviet Union, as well as in their military postures, missions, capabilities, and costs.[3] Where qualitative differences are relatively small, existing heuristic rules can be used to estimate how much technical advantage is needed to compensate for numerical inferiority in a variety of circumstances, and balancing the increase of relative performance against the cost.[4] Recent criticism of U.S. weapons policies make the more specific assertion that we are no longer trading on the margin, that the current push for ever more sophisticated weapons and weapons systems has removed our ability to exploit our technological advantage. Our weapons have become so complex that they are too expensive to buy in adequate numbers, too difficult to support and maintain, and take so long to develop and deploy that much of the putative technical lead is dissipated before they can be effectively deployed.[5]

It is all too easy for debate over these issues to become mired in details of specific weapons technologies and systems, arguments about specific U.S. capabilities and needs, and conflicting assessments about the demands imposed by the current politico-military situation. In so doing, all parties neglect the extent to which the issues at stake are not wholly derived from proximate circumstance, and thus not wholly resolvable by arguments predicated largely on short-term analyses, but are based on attitudes and beliefs about what is and should be a "proper" posture for U.S. weapons acquisitions policies that in themselves derive from historically formed socio-political and socio-psychological attitudes than from assessments of current threats, technical logic, and rational calculation.

The several programs that make up the Strategic Computing Initiative must also be discussed in these broader terms if we are to gain a comprehensive understanding of their motivation, probable development, and possible long-term implications. Even a cursory survey of the programs as set forth leads to the conclusion that none of them responds to any pressing military or policy requirement, or seeks to exploit already existing mature technical potentialities.[6] Rather, the overall program seems framed by confluence of three historical trends in technical choices for U.S. military forces.

The first and most persistent is a continuing debate over the choice between weapons and systems designed for precision and range and those emphasizing mass fire that appears to have gone on for more than a century. From the Civil War through Vietnam, official U.S. policies have tended to favor the "sharpshooter" approach—accurate, long-range weapons with a relatively low rate of fire—in time of peace, while soldiers at the front in time of war have consistently sought maximum rate of fire at comparatively close range (the "shotgun" approach).

The origins of the second trend lie with the striking success of scientific and technological innovation during and just after World War II, combined with a long-standing U.S. belief that technology can be used to solve almost every outstanding problem, be it civil or military, even when its origins and manifestations are largely social, economic, or political. The U.S.

has always had an ongoing flirtation with technology in the form of invention, raising such inventive entrepreneurs as Thomas Edison, Henry Ford, and the Wright Brothers to the status of heroes. With the visible harnessing of science to technology in the 1940s, scientists and engineers became the parents of invention, moving from the periphery of political power to its very center. Their newly-acquired influence was based primarily on the conviction of the U.S. in general, and policy-makers in particular, that innovation need not come from the efforts of isolated genius, but could by systematically generated, developed, and deployed as and where needed.[7]

Over the past two decades, the introduction of sophisticated communication technologies has made decision-making more time-urgent just as a combination of other technical and social factors have made decisions and processes more complex, more difficult to grasp, and more uncertain of outcome. In the past few years, computer technologies have moved to center stage. As hardware became faster and cheaper, and software evolved to take advantage of increasing speed and capabilities, computers began to be seen as a potential solution to rapid decision-making in the face of complexity and uncertainty. Thus, the third and newest factor—the belief that computer-based technologies and systems now or soon to be available can control situations too time-urgent, complex, or critical to trust to fallible and sometimes unpredictable humans. As stated in the Secretary of Defense's Report to Congress for FY 1986, under the heading of "Strategic Computing":[8]

> . . . advanced expert systems will be developed that can store and manipulate knowledge in any of these fields to allow machine-reasoning and inferencing . . . High performance computers will be needed to carry out these functions to meet the real-time demands of field operations.

Thus, the Strategic Computing Initiative, with its emphasis on "artificial intelligence" and expert systems, should be judged not just as an attempt to turn the latest products of American scientific and technological talents to military use. On a deeper level, it is an attempt to defy the historical forces of complexity, uncertainty, and chance in combat by controlling not only battle losses, or outcomes, but the very processes by which the battles are fought.

The Myth of the Marksman

The legendary ability of a small body of elite troops to overcome near-over-whelming numerical inferiority through accurate, aimed fire has been a persistent element of U.S. beliefs at since the Revolutionary War, and its origins probably lie much further back in the history of Medieval England.[9] The exploits of the highly-skilled individual soldier have been lauded in popular culture consistently, from Robin Hood through Sergeant York to the ace pilots of WWII. To some extent, this is surely no more than hero-worship in a form familiar since Homer, albeit often encouraged and promoted by those in power for political ends. But it also seems to reflect a peculiarly American reluctance to admit, in time of peace, the losses that will be incurred in time of war, and to deny even in the heat of war the true costs of modern warfare.[10]

The legend of the longbow is perhaps the most famous, and certainly the most durable example. The considerable skill required to make the longbow into an effective weapon demands constant practice as well as good training. Thus, the promotion by Henry III and his successors of yeoman skills for the defense of the realm. Encouragement of target shooting and competitions were useful strategies for encouraging practice and rewarding the development of skill, but it was its rate of fire rather than its accuracy that made the longbow such a deadly weapon.[11] Robin Hood and other legends may have served to preserve and reinforce the legend that the longbow was superior as an individual weapon to the crossbow (which requires far less individual skill and practice), but the latter was clearly the technologically superior weapon in all aspects other than rate of fire.[12] Although the victory of Edward III over the French at Crecy in 1346 is a fundament of the sharpshooter legend, there was little directly aimed fire from the English archers, who simply fired as rapidly as they could into the mass formations charging towards them. It was this "hail of arrows" from the English that felled first the Genovese crossbows (who had to stop and kneel to re-arm their weapons), and then the French knights rushing impatiently after them. By the end of the day, the archers at Crecy had ended forever the supremacy of the mailed and armored knight as a "weapons system" and firmly established the legend of the longbow as a technologically superior weapon.[13]

This interesting dualism between the legend of accuracy and the reality of mass fire has persisted down through British and American history. The British, for example, were quite proud of the marksmanship of their first rifle units during the early part of the 19th century. But these were also issued large numbers of sub-caliber bullets for general use to increase their rate of fire—except except during those *extraordinary* circumstances where aimed fire was needed.[14] The period during and after the U.S. Civil War provides more examples of the mythology of marksmanship, with both sides proud of an accuracy that mattered little on the battlefields. In fact, the term "sharpshooter" first described those Union troops who were issued the very accurate Sharp rifle. But these were specialist and sniper units, and the slow-firing, breech-loading Sharp was issued to very few ordinary soldiers. By far the most effective weapon of the war was the Union's 7-shot Spencer repeating rifle—"the gun the Yanks load on Sunday and fire all week."[15] Yet, the U.S. refused to adopt it after the war—on the grounds that it was not accurate enough for military use—and retained the single shot breechloader as the standard Army issue from 1867 through 1892, when Congressional pressure forced the adoption of the Krag-Jorgensen magazine rifle.[16]

This fascination with long-range accuracy in rifles has persisted in the U.S. Army to the present day.[17] The bolt-action 1903 Springfield, perhaps the most accurate military rifle ever developed, was of limited use in the heavy fire of WWI trench warfare. Even the machine-gun, despite its demonstrated effectiveness in the limited wars at the end of the Nineteenth Century, was not fully integrated into Army units until the bloody battles of 1915-16 proved beyond doubt the diminishing utility of aimed fire.[18] At the end of WWI, the army sought to replace its 1903 single-shot Springfields with a semi-automatic rifle. After more than a decade of debate over caliber and ammunition compatibility, it finally adopted the famous Garand M-1 in 1936. But the Garand too was a compromise, with a long heavy barrel for accuracy at range and no "full automatic" over-ride; moreover, the recoil from its heavy-caliber .30-'06 bullet made it very difficult to aim at all in rapid fire.[19]

From WWII through Korea to VietNam, the U.S. refused to heed the demands of its soldiers for lighter weapons with a higher rate of fire. The M-14 that replaced the M-1 in 1959-60 did have a full-automatic mode, but it was still primarily a heavy-caliber marksman's rifle, barely controllable even when firing semi-automatically. Even in the jungle conditions of South East Asia, where firepower was at a premium against an enemy armed with less accurate but more durable fully-automatic weapons, and where U.S. soldiers could rarely see as far as their weapons' maximum accurate range, the Army had to be forced to adopt the Armalite AR15 instead of its bulky and slow M-14—and then almost destroyed its reliability in a process of systematic "militarization" to turn it into the much-maligned M16.[20]

This is not to say that there is no place for range and accuracy in weapons. There are places and circumstances in the world where such combats do take place. In Naval surface combat, in light skirmishes across open country, in one-on-one air combat, and in any circumstance where accuracy at range may determine the outcome of individual combats, and the survival of individuals or individual weapons systems is indistinguishable from achieving military objectives, the quality of individual weapons becomes paramount.

Such conditions have typified the various Arab-Israeli conflicts, most notably in the recent duel with Syria in the Bekaa valley of Lebanon, where U.S.-made aircraft and Israeli tanks scored such one-side victories.[21] The primary mission of U.S. forces, however, remains the deterrence of the Soviet Union on the central front in Europe, where limited combat areas and the number and density of weapons virtually guarantees that most combat will take place at high density and close range. Under these conditions, and in particular at times when the weather is bad, survival depends more upon total firepower and quick and correct reaction than on precision and range, and victory may turn more on the ability to replace troops and equipment than their sophistication, accuracy, or training. And survival and replacements are crucial issues if we are to avoid enormous pressures to shift to nuclear weapons early on to stave off an imminent defeat.[22]

In the past, the slowness with which any war was likely to develop and the relative decoupling of the U.S. from potential wars in Europe or Asia made the U.S.'s peacetime posture reasonable. The U.S. could avoid the maintenance of large standing forces, since it was capable of absorbing substantial loss during the mobilization period. Its small, highly-trained elite forces were asked only to hold critical positions, and only until U.S. industrial strength could be re-organized for war. Arguments for insisting on the highest possible quality for the weapons given to those small standing forces could be defended on the grounds that their holding role was critical and the forces themselves irreplaceable. But once the U.S. became fully engaged, the emphasis was on mass production, huge armies, and our ability to replace both. Once its forces enter into actual armed combat, the U.S. has been no more able, or willing, to minimize its losses than any other Western country.

From the Civil War down to the present, America's primary asset in war has been its industrial strength and productive capacity. From before the Civil War to after Korea, arms and armaments have been built with the same technology and by the same factories that were previously engaged in the mass manufacture of civil, industrial, and consumer goods. The "defense industrial base" was always in place and ready, with only time and money needed to turn its output to wartime production. It is true that peacetime requests for new weapons or systems often run afoul of other governmental pressures to economize, which often argue for maintaining old stocks and ammunition rather than changing over. But it is equally true that innovation is discouraged at the beginning of a conflict for the sake of production. Whatever the pre-war pace of innovation, it was suppressed at the outbreak of war in favor of standardization to increase output, at least until the initial elite corps could be replaced with mass-conscripted troops with their mass-produced weapons.

The Myth of Technology

During WWII, the U.S. and its allies were eventually able to harness scientific and technical innovation to the brilliant solution of a number of pressing military problems—

operations research (to hunt submarines), radar, cryptography, and, eventually, the atomic bomb. In the aftermath, it was therefore easy to believe that the U.S. and its allies were throughout the most innovative and technically advanced. But application of technological and scientific innovation to new approaches and systems did not extend to basic, mass-produced weapons systems for several years. Especially in the early stages of the war, German and Japanese aircraft and tanks were not only the equal of any possessed by the allies, they were in many respects superior.

The Luftwaffe is an excellent case in point. Hitler had not planned for a long war, and did not shift to full mass production of aircraft until late in 1941, allowing the industry to innovate and change models even at the cost of production rates. As Murray points out:[23]

> Delays imposed by the search for quality were a major factor in minimizing aircraft production. Indeed, the quality versus quantity dilemma was a factor Milch never succeeded in reconciling with the German industrial system. Right through 1944, German aircraft possessed the finest upholstered crew seats; thousands of man-hours were wasted in machining bulkheads and minor fittings, while parts taking no strain or requiring no precision were finished to close tolerances. The completed aircraft represented a finely finished product compared to their American and British counterparts, but where there were hundreds of the latter, one found only tens of the former.

The allies, in the meanwhile, froze their designs. Not until late in 1942, when production rates were clearly adequate to keep supply lines filled, did they allow for any technical innovation that could not be readily incorporated into existing manufacture.[24]

Nevertheless, the notion that the U.S. had won the war through its technical supremacy persisted, greatly reinforced by the notion that the Atomic Bomb was what had finally defeated Japan. In the aftermath, scientists and engineers, were given unprecedented respect and direct influence in government, especially with regard to military matters. The growing American tendency to accept a technological solution to any problem, whether physical or social, has long been noted.[25] And with no social or political constraint in place, the process of generating new technologies becomes self-propagating.[26] What gave it unique power in the case of military forces was its confluence with the long-standing myth of the marksman, and our historical reluctance to maintain large standing armies—especially if universal conscription is entailed.

What was expected of the scientists and engineers in exchange for their new power and prestige were technical solutions to such largely non-technical problems as containing the influence of the Soviet Union or building an effective global military force with minimal personnel and a very restricted budget, a policy formalized by Eisenhower's "New Look" defense policy of 1953, which was specifically intended to control the military budget through exploitation of our technological advantage.[27]

The Cost of Innovation

There is a certain irony in the economic and military results of our thirty-year effort to control the size and cost of our forces with advanced technology. At the end of WWII, a brand-new top-of-the-line fighter aircraft (the legendary P-51 Mustang) cost about $250,000 (in 1983 dollars), and was being produced at the rate of several thousand per year.[28] By the time of Eisenhower's declaration of the New Look, the price of the latest fighter aircraft (the F-86 Sabre) had risen to about $1,000,000 (in 1983 dollars). More than 6,000 were built in 1950-53 alone as part of the Korean buildup.[29] Our first-line fighter in Vietnam was the multi-purpose two-seat F-4 Phantom, whose cost (in 1983 dollars) exceeded $6,000,000. With the exception of 1966 when 600 were purchased, purchases were generally held to about 200/year.[30] By the 1980s, purchases of all combat aircraft of all types for all the services were less than 600 per year, largely because of rapidly escalating costs. The F-15 Eagle, our current first-line fighter-interceptor aircraft costs more than $25,000,000 1983 dollars, and purchases are projected at the level of no more than 60 per year, even under the current accelerated programs.[31] Even the "low-cost" end of the high-low mix, the F-16, costs more than $15,000,000 1983 dollars, and the current (accelerated) five-year procurement plan only calls for about 1,000 additional purchases (200/year), even though the F-16 is also being carried as a major component of our tactical ground-attack forces.[32]

Procurement rates for almost every type of major weapon system— aircraft, missiles, tanks, ships, etc.—have dropped dramatically in recent years owing to their rapidly escalating unit costs.[33] Why do these costs continue to escalate? The standard explanation—the increased complexity of modern aircraft with their advanced materials, demanding electronics, and so on—is not persuasive. One of the most remarkable features of the past decade has been the precipitous decline in the cost of civil and industrial electronics of all sorts—accompanied by an equally remarkable increase in its diversity and capability.[34] Yet, the electronics alone for a modern fighter such as the F-15 are estimated to account for perhaps one-quarter to one-third of the total price—more than the (inflation-adjusted) cost of an entire F-4 some 15 years ago.[35]

Nor have other weapons systems been spared this escalation in cost and complexity. Similar data may be explored for surface and submarine vessels, for tanks and armored cars, for missiles of all kinds, and for a variety of ground and air weapons.[36] Only the lowly rifle seems at last to have escaped, for the moment, the urge to automate, radar-detect, laser-direct, and centrally-command all aspects of the battlefield.

The consequences have been serious. Even if one stipulates the necessity of adopting something close to the state-of-the-art in technology as a counter to presumed Soviet superiority in personnel and numbers, pushing for the state-of-the-art itself has been very costly. If technologies were frozen at the time of weapons choice, and if the technologies chosen were relatively mature, the systems could be developed and deployed relatively quickly, and efforts shifted towards the next generation of systems. If technologies were chosen to adapt to present military capabilities so that systems evolved gradually instead of changing radically from generation to generation, costs would be reduced.[37] But we seem unable to resist the urge to adopt the very latest in technology for our weapons systems, even though this vastly increases their costs, or to resist the pressure to constantly revise them during development and even during production, to incorporate the latest advances. .

A prime example of the interaction of technical innovation with premature closure due to fear of uncertainty is in the design of new aircraft. As described by Luttwak, the usual behavior for a military contractor is to force conceptual design into a definite product too early in the development process, yet using technologies so far from commercial practice that development takes many years.[38] Over this long period, other technologies that could improve performance or lower costs can appear on the horizon. Given the susceptibility of all involved to the promise of new technologies, the design-frozen system may be extensively re-designed, which often entails large cost over-runs and even further delays in availability.[39]

The result is a vicious circle in which the promise of new technologies lead to long gestation times and long delays in deployment, preventing gradual evolution while increasing price and reducing the number of systems we can afford. The by now long-delayed and very expensive systems are thereby seen as far to valuable to expend casually in battle, especially against numerically far superior Soviet forces, which in turn reinforces the pressure to incorporate even more modern technology to make them more accurate and survivable. What is more, the push to use the most modern electronic and materials technologies not only divorces military systems from civil technology, reducing our ability to come up with replacements in time of war, but vastly increases their complexity, making the weapons less available, harder to maintain, and possibly so fragile in time of real war as to vastly reduce the number available for combat at any given moment.[40]

But all of this deals only with the weapons themselves, whereas the most complex and demanding functions of modern weapons and warfare is supposedly the exercise of command and control. And in this area, where tradition means little and technology reigns supreme, where the impacts of the SCI and other developments relating to modern computer technologies will be most quickly manifested.

The Myth of the Computer

The one term that is most commonly used to characterize the technological developments of the past decade, particularly with regard to computers, is the "information revolution." And it is certainly true that progress in communications and data transmission and storage have resulted in a quantum leap in our ability to transmit large bodies of factual material with facity to almost everywhere on the globe, to communicate as readily with distant as with local terminals, and, at least in principle, to exercise not only supervision but control over a variety of real-world actions remotely, yet in real time.

If current magazine and journal articles are good indicators, this will soon be supplanted by other signifying phrases derived from the field of artificial intelligence—in particular, "knowledge-based" or "expert" systems. Their increasing availability stems less from theoretical progress than from the steady increase in user-available capacity as computers grow in capability and shrink in size and price. With the advent of sophisticated relational data-base managers, computers changed from "data banks" to "information processors." And now, the rapidly increasing ability to implement decision systems based on large and analyzable data stores has led to the possibility that a variety of more or less routine decisions can themselves be delegated to a knowledge-based "expert system", whose predictability and reliability will supposedly far exceed those of fallible and often inattentive human beings.

Many observers have cast a critical eye at some of the potential implications of such a technological change, including at least some consideration of such "social impacts" as job qualification, alienation, employment patterns, etc.[41] Less well understood, particularly by those whose notion of social impacts are largely confined to either the personal or the global level, are the implications of such potential for the organizations and management systems that put them to use, whether they be public or private, civil or military. Such systems offer the managers of large, complex organizations what appears to be the potential to reduce internal and external uncertainty by exercising direct and real-time control over a wide variety of operational and managerial activities, and uncertainty ranks above almost every other consideration as a cause of anxiety among managers.[42]

In the common parlance, the raw input stream consists of "data", which are transformed by suitably clever electronic systems into "information" to be presented to the operator. And, with appropriate integration and judgement, whether by the human operators or their machines, this information is in turn translated into "knowledge", which can be expressed in many terms: as knowledge about the course of the firm's profits, as a net assessment of the current threat environment, or as wisdom about long-term market trends. Such casual use of terminology, characteristic of common discourse, not only lacks the precision required for thoughtful analysis, but misleads promoters and users alike as to what the real capabilities of these new systems might be.

Data, precisely defined, are no more than a stream of words, numbers, or pictures whose function is the symbolic representation of some real-world situation. But without a theory with which to interpret them, the data themselves are meaningless, however they are accumulated, organized, analyzed, and re-organized, by however powerful a computer or human brain. It is a common flaw to confuse data per se with the information they can convey when theoretically ordered, or the knowledge (even wisdom) that can be derived from the testing and evaluation of one or more theoretical constructs.

Thus, the first myth of the computer age is that the data themselves constitute information, or knowledge, or wisdom.[43] And, thus, the mad rush by thousands (soon, perhaps, to be millions) to accumulate, store, organize, tabulate, and argue over vast, structured collections of individuated numbers, tables, figures, and facts as if by so doing they might be said to be wise.

Information has two definitions, one common, one technical. In its most technical definition, information must contain some element of the unexpected. If the stream of incoming data is precisely what is expected and anticipated, it conveys no "information" in the technical sense—even if it does, in the common sense, convey the often-important "information" that nothing unexpected is happening.

Knowledge is the most difficult to define in common-language terms because it means so many different things to so many different people—and many different things to the same person at different times. Rather than engage in epistemological discourse, let us take a definition of knowledge that uses theory to mediate a relationship between information and knowledge consistent with and derived from the preceding discussion on data and information. In these terms, "knowledge" is a theory that has been fully confirmed by a flow of information over time. Where knowledge (rather than mere hypothesis) exists, data provide *con*firmation rather than *in*formation, the incoming data stream contains no surprises, and therefore no longer informs.[44]

What many people pass off as knowledge, particularly in organizational contexts, often amount to no more than hypothesis—speculations that are not empirically proven, however reasonable—or various predictive theories that may have been arrived at through induction from historical data and trends, but have not been fully tested or verified against predictions of future behavior. More often than not, organizational decisions about future behavior are based on little more than the accumulated folk-wisdom of past actions. The all-too common tendency to build projective decision models based solely on past data is only reinforced by the computer, which lends an air of technical sophistication to what is basically no more than an extrapolative exercise.

Thus, we arrive at the second great myth of the computer age—the "inductivist fallacy" that knowledge (in the sense given above) can be arrived at through the clever and sophisticated manipulation of sufficiently large and varied collections of data, and that what is so derived is not only a reliable, but a "scientfic" guide to the course of future events.

The "Control" Fallacy

Some of the organizational consequences of similar conceptual errors have been examined by Landau and Stout in the general context of the management of civil organizations—be they bureaucracies or firms.[45] They make the case that there is no such thing as a "management control system", for management and control are two different classes of administrative behavior.[46] "Control" implies the ability to determine events and states of affairs so closely that for every causal factor there is a completely predictable outcome. This in turn requires near-perfect "knowledge" in the sense of the preceding discussion. If knowledge is complete, then present circumstances can be completely decomposed and analyzed, event chains built on them can be evaluated with near certainty, and our "predictions" will be in error only if the rare random event completely outside the scope of our knowledge occurs. Thus, the stream of data become information only at the point where the adequacy of the guiding theory is called into question.

For a control system, data serve only the role of confirmation and reassurance, they convey the single piece of "information" that the knowledge base and the control structures built on it continue to function. When data supply the additional information that the outcomes are *not* proceeding according to predictions, theory is inadequate, the basis for control is eroded, and those in charge must re-construct their knowledge base before control can be re-asserted. If management and administration are unprepared for this contingency, they have no mode for reacting other than to try to re-establish control within the pre-existing theoretical framework. In many cases this inability to recognize the full implications of events can result in serious risks—to the organization, the tasks it manages, or the general public.

"Management", on the other hand, implies a continual process of decision-making based on reading input data, comparing it with objectives and goals, and continually adjusting organizational structures, functions, and duties to reduce the "error signal."[47] Such an organization treats its environment not as a solved problem but as a continuous experiment. Because the input data stream is thereby set in a theoretical context, it does indeed contain some information, in the strictest sense given above, as well as the usual "noise" component.

Where officials treat as subject to management a problem that should be controlled, they make a "Type I" error—equivalent to rejecting as false a hypothesis which is true. Such errors tend to be relatively benign, as the net cost rarely exceeds simple inefficiency. Organizations that consistently make errors of this type may suffer needlessly the pangs of uncertainty where none exists, and resources may be wasted in attempting to interpret, analyze, and act on data that contain no real information. Only where the waste begins to impair the ability of the organization to carry out its public role do errors of this type become noticeable.[48]

Where officials treat as controllable a problem or set of problems that should be managed, the error is "Type II"—equivalent to accepting as true a hypothesis which is either false or not provable. The serious implications of this case and admirably set out by Landau and Stout:[49]

> Type II errors are in themselves delusions. They are fixed *a priori* commitments which reify the the theories upon which control is based and substitute them for the real world. This happens because "controllers" cannot permit their decisions, orders, rules, and regulations to be maintained as hypotheses. . . . . These carry a high degree of subjective certainty (which means that the controllers believe their own facts) and are easily converted into a dogma.
>
> In this type of goal displacement, officials cannot bear disappointment, and they cannot learn of failure. It shakes the faith. Upon the appearance of a discrepancy, the search is for deviants, not deviance. Discrepancies are seen as compliance problems, not as tests of the empirical adequacy of the control system.

It is not surprising that "controllers" will choose to ignore or discard data rather than rejecting the theories that underlie their entire management strategy. In a control-based system, "error" becomes a pejorative term that describes not the normal process of adjustment to an uncertain future but personal incompetence or organizational failure. Incipient errors will not be recognized or acknowledged until their consequences are so serious and apparent that those outside the organization are affected. This misconception of the importance of error and its value to the organization is perhaps the most serious consequence of adopting control as the dominant administrative metaphor. Where organizations are being managed effectively, the detection and discovery of error is not only routine, it is encouraged.[50] Errors constitute the information that managers seek, the measure of the deviance from expected behavior that they are bound to try and reduce. Without error, there can be no corrective action, and without corrective action there is no management.

Command or Control

If mistaking control for management is a trap that even the most "civilian" of bureaucracies can fall into, imagine how much more vulnerable are military or military-related organizations, where compliance is the rule, competition for promotion at the command level is fierce, and the very structures of command place a great premium on the illusion of certainty.[51] What is often implied in the justification of new, high-technology systems is that the battle itself, if not the battlefield, can be centrally directed, coordinated, and controlled.[52] This would have amused the great generals of history, who harbored no such illusions about the uncertainty of combat and the "fog of war". Perhaps the most famous meditation on this point is that of Tolstoy in the midst of the Battle of Borodino passage of *War and Peace*:[53]

> The conditions in which a commander-in-chief operates in the field have no sort of resemblance to the conditions we imagine to ourselves sitting at our ease in our studies and going over some campaign on the map . . . starting our plan from some given moment. A commander-in-chief never finds himself at the *beginning* of an event—the position from which we always contemplate it. The general is always in the midst of a series of shifting events and so he can never at any point deliberate on the whole import of what is going on.

What generals must do, suggests Tolstoy, is to manage the battle as it comes; preset plans are certainly useful, even necessary, but rarely bear much relation to the actual combat as it unfolds. Napoleon's great plan for Borodino, much admired by historians, was never carried out. Nor could it be, since the real forces were from the beginning never disposed according to the arrangements the plan specified.

Great generals and admirals, are often great because they have prepared alternatives, have anticipated contingencies, and have been able to detect incipient errors and adapt to them on the fly in the midst of a confusion that paralyzes lesser men. More often than not, the battle has gone against the least flexible and adaptable side—the one with the most rigid, pre-programmed tactics.[54]

Command and control can therefore be seen as a dialectic of battle rather than a synthesis. In the heat of battle, control can be applied only loosely and at the most general level. The successful general officer understands the limitations on his information and the generality of his plans and models, and exerts real "command" by managing his forces wisely through the acceptance of error and its rapid correction.[55] Time and time again, generals and rulers have tried to intervene when they imagined that the information (or knowledge) they possessed was superior to that of the field commanders.[56] The temptation to move increasingly from "command" to "control" will only be exacerbated by advanced technologies that purport to present to commanders a complete, comprehensive, and interpreted summary of the current situation, presenting an unprecedented opportunity for direct "micro-management" of all aspects of the battle.[57]

The Strategic Computing Initiative

Seen from these more historical and socio-political perspectives, the Strategic Computing Initiative (SCI) is not radically different in conception from what has gone before it. Where it differs is that it represents the confluence of these several factors. Given the imperative for technical change and the costs that entails, the concern for marksmanship and the preservation of individuals has been transformed into concern for the weapons themselves. The technology that makes them so expensive and complex, and therefore so rare, vulnerable, and valuable, also holds out the promise that both their combat environment and their use in combat can be carefully controlled to avoid uncertainty and reduce losses, and that incredible kill-ratios can be achieved.[58] The three specific subprograms of the SCI, are therefore not unique, but representative of the socio-political motivations that shape the choice of technologies for U.S. military forces.

Consider first the Army's slice of the SCI pie, the Autonomous Land Vehicle (ALV). In principle, there is much to be said for a vehicle that can be sent under remote control into particularly dangerous circumstances such as minefields, unknown enemy force concentrations, etc. One would imagine, however, that such a vehicle would have to be considered expendable, and that cost would therefore be a primary consideration. Moreover, a vehicle sent into unknown circumstances should probably be "managed" remotely via a radio or similar link to allow for quick improvisations and changes in plan. But if remote controlled, the ALV will be subject to jamming, multiple signals, and a variety of other forms of interference. If controlled internally by an expert system, it will carry with it a repertory of responses pre-determined in consultations with "experts" who themselves may never have imagined, let alone encountered, the circumstances in which the vehicle finds itself. Perhaps this is a bit unfair to the Army, for the ALV would appear to exist primarily to assure that the comparatively low-tech Army had a slice of the joint pie.[59] But the Army is hardly doing better with some systems it has sought out on its own, such as the M-1 tank, the Bradley armored vehicle, or the "Sergeant York" (sic!) air defense gun.[60]

The Air Force slice of the SCI is the expert system for the F-18 fighter. As with the ALV, the concept itself could well be applied intelligently. Given the enormous complexity of F-18 avionics, and the number of things its lone pilot must keep track of in the absence of a radar/weapons officer in a second seat, the F-18 pilot can use all the help he can get.[61] This is certainly an application for which "merely competent" expert systems could be of great assistance— especially if they are used as an auxiliary and warning system to the pilot rather than as an attempt to supply the missing second man in the cockpit.[62] The question is not whether a competently designed and competently installed system could help, given the complexity of tasks facing the single pilot of the F-18, but why such a complex set of tasks should be assigned to a single aircraft with a single pilot. Moreover, there is some understandable concern as to how many tasks, and of what kind, will eventually be assigned to the electronic "pilot assistant", and whether the pilot's acquired dependence upon routine operation will increase or decrease effectiveness and survivability in combat.

The third member of the SCI menage is the battle management system on the U.S.S. Carl Vinson. As with the expert system on the F-18, there is considerable room for the application of competent "expert systems" for a variety of tasks. For example, an air traffic control system could be useful for managing traffic in and around the carrier, where quick decisions based on fixed rules might be helpful in relieving the carrier's "air boss" of routine calculations so that attention can be turned to those where human judgement is critical.[63] A computer-aided system might be designed to sort out the various incoming weapons if a carrier was under attack, enabling it to turn its defenses to the most immediately threatening. And expert systems might be used for a variety of other combat-related tasks such as evaluating the nature, course of, and probable threat from a variety of aircraft and vessels within some critical range. But once again there is some concern as to how many tasks will ultimately be transferred from human to computer decision-making. And, as with the F-18 system, if the system fails at a crucial moment (as is quite likely in actual combat), human operators, deprived of constant experience and practice, may no longer be able to step in and perform effectively those tasks that had been given over to the automated system.

Conclusion

All of the applications suggested under the Strategic Computing Initiative could well turn out to be reasonable and appropriate—*if* the the nature and limitations of technologies, even those as advanced as "artificial intelligence", were understood and adhered too. But in all of these cases we see reflected in supposedly proximate and data-based policy decisions the three tendencies sketched out above: the inability to "objectively" consider the trade-offs between sophistication, complexity, availability, and costs; the search for technical solutions to military and procurement problems that are largely non-technical; the attempt to control rather than manage in the face of uncertainty and complexity. These provide the basis for real concern that we will continue to seek solutions at the cutting edge of new technology. It seems almost certain that the weapons and systems that result will therefore follow the most recent historical trends in being far more costly than their predecessors, available in even smaller numbers, and more subject than ever to delays, retrofits, and maintenance bottlenecks.

These are important considerations for all those who worry about the projected costs of maintaining a credible mix of conventional military forces for the U.S. Most crucial is whether increasing cost and complexity so reduce the number of existing systems and the ability of the "defense industrial base" to replace them that we will run out of them too quickly in a major conflict with the Soviet Union (e.g., on the NATO central front). If our very few and very complex systems prove to be to difficult to maintain in combat, ineffective, or are consumed too rapidly, we may be faced at a very early date with the painful choice between going nuclear or going home.

Nor is it very reassuring to discover that the Soviets are moving in more or less the same direction.[64] For that only puts them in the same position if it is the Warsaw Pact that finds itself running out of its most advanced weapons systems too quickly. The central role for all conventional weapons systems in all super-power conflicts, real or potential, in the nuclear age is to survive long enough to provide if not a stalemate, at least the time to negotiate a conventional cease-fire and not to provoke the early use of nuclear weapons.

Yet, none of the three projects identified thus far seems to warrant undue concern at this time. All three projects are comparatively modest in scope, highly experimental, and have the potential to be put to appropriate use if adequate oversight and management can be provided. What is at stake is not these systems themselves, but what they signify in terms of the next generation of technological change in military systems.

In that sense, current NATO and Warsaw Pact plans for the total, automated, integration of all command and communication functions on the central European front may be the most significant warning of the future. The U.S. version, "AirLand 2000", is based primarily on an elaborate network of land, sea, and air-based real-time communication links that are planned not just to inform, but to supply real-time inputs to computerized "machine-reasoning and inferencing" automated control technologies. In the short run, their apparent purpose is to allow commanders to attempt to control details as well as the overall conduct of battle, to replace command on the spot with control from HQ.[65] But their ultimate purpose—to move the ultimate decision-making authority from the hands of the staff and onto the faster and more predictable automated control systems—is also clear.

It is no great feat to imagine the extension of such systems to other time-urgent critical tasks such as ballistic missile defense, or even the control of major portions of our nuclear deterrent, where the time pressure is so great, and the potential consequences so large, that learning from trial and error seems impossible. Under such circumstances, there is a particular seductiveness to the notion that control can be substituted for management and technology for human judgement, ignoring the imperfection and speculativeness of our models. The illusion of perfect knowledge that underlies the belief in complete control could therefore put us all at ultimate risk, with our fates, and the fate of the world, dependent upon the validity of a set of empirically untested, and perhaps untestable, hypotheses upon which the computers' programs are based.

NOTES

1. See, for recent examples: Edward N. Luttwak, *The Pentagon and the Art of War* (New York: Simon and Schuster, 1984); Asa A. Clark IV, Peter W. Chiarelli, Jeffrey S. McKitrick, and James W. Reed, eds. *The Defense Reform Debate: Issues and Analysis* (Baltimore: The Johns Hopkins University Press, 1984), particularly "The Case for Better and Cheaper Weapons" by Pierre Sprey, pp. 193-210; Franklin C. Spinney, *Defense Facts of Life: The Plans/Reality Mismatch* (Boulder: Westview, 1985). Most widely known is James Fallows, *National Defense* (New York: Random House, 1981), which first presented to a general audience the then in-house critiques of the budding "military reform" movement.

2. See, for example, William J. Perry, "Defense Reform and the Quantity-Quality Quandary" in Clark et al. *The Defense Reform Debate*, 182-192.

3. Perry, "Defense Reform".

4. For a recent example that tries to go beyond individual weapons systems trade-offs into the more complex question of overall force effectiveness, see Joshua M. Epstein, *Measuring Military Power: The Soviet Air Threat to Europe* (Princeton: Princeton University Press, 1984).

5. There is also some concern about the "Mary Rose syndrome". Henry VIII's flagship and the pride of British naval design in the mid-1600s, the Mary Rose was so over-designed and overgunned that she heeled over and sank on her way to her first engagement. (*The Economist*, 16 October 1982, 48).

6. It can also be argued that the SCI is to some extent an adaptation by DARPA to a current political climate that demands demonstrable "hardware" as the price of continuing support for basic computer science research. Although based on immediate rather than historical socio-political factors, this intriguing argument complements the one set out above.

7. Vannevar Bush, *Modern Arms and Free Men* (New York: Simon and Schuster, 1949). The most cogent analysis of the scientists' rise to power is still that of Don K. Price, *The Scientific Estate* (Cambridge MA.: Harvard University Press, 1965.

8. Caspar W. Weinberger, Secretary of Defense, *Annual Report to Congress, FY 1986* (Washington D.C: U.S. GPO, 1985), p. 267.

9. It should be noted that historical Continental powers such as France and Prussia could afford to maintain large standing armies, since there was always something to keep them employed "elsewhere". That large standing forces would be a perpetual problem on a relatively small island may have also contributed to British reluctance to maintain mass conscript armies until it became a global power. Instead, the British and American convention has leaned heavily on the principle of voluntarism except in time of war. As John Keegan has astutely pointed out: "In France, Russia, and the lands of Central Europe, ... the literary convention is to portray war as corporate experience . . ." while "The Anglo-Saxon convention, on the other hand, is intensely individualistic and reportorial . . ." (John Keegan, "Britain and America", *Times Literary Supplement*, 17 May 1985, 544.)

10. Consider, for example, the persistence of the notion that U.S. bombing raids in WWII were precisely aimed at predominantly military targets, thus minimizing civilian casualties.

11. Col. Trevor N. Dupuy, *The Evolution of Weapons and Warfare* (London: Jane's, 1982), 82ff.

12. Vernard Foley, George Palmer, and Werner Soedel, "The Crossbow", *Scientific American*, **252**, No. 1 (January 1985), 104-111.

13. The legend that the longbow was *technologically* superior to the crossbow (especially with regard to range) is amazingly persistent even among military historians. See, for example, I. B. Holley, *Ideas and Weapons* (New Haven: Yale University Press, 1953). This may arise partially from confusing the superior training and skill of the longbow archers with the capabilities of the weapons themselves.

14. The rifle was actually available as early as the sixteenth century, but its low rate of fire made it useful only for skirmishing and sniping. The musket remained supreme because of its rate of fire until the invention of the Minie bullet in the mid-19th century gave the rifle a comparable rate of fire. William H. McNeill, *The Pursuit of Power* (Chicago: University of Chicago Press, 1982), 232 ff.

15. Even so, it was not widely adopted even by the end of the war. Despite its industrial superiority, the North fought with pretty much the same breech-loading weapons as did the South, increasing their firepower through mass conscription. (Holley, *Ideas and Weapons*, p.10 cites the original 19th century analyses to this effect).

16. Thomas L. McNaugher, "Marksmanship, McNamara and the M16 Rifle: Innovation in Military Organizations, *Public Policy*, 28, No.1 (Winter 1980), 1-37, p. 7. Almost every civil rifle was a Spencer-based repeater by that time. The victorious Indians at Little Big Horn, not having been exposed to Army doctrine, preferred their Spencers. They did not even bother to collect the army breechloaders that were lying about. See Fallows, *National Defense*, pp. 80-82.

17. McNaugher identifies this attitude as "distinctly American", pointing out that both the French and the British perceived the advent of the quick-firing rifle as heralding the age of controlled, long-range mass fire (shades of Crecy!). Thomas L. McNauger, *The M-16 Controversies: Military Organization and Weapons Acquisition* (New York: Praeger, 1984), pp. 17-20.

18. The American ground forces "hero" of WWI was of course a "sharpshooter"—Sergeant Alvin York—whose heroic capture of an entire German company was attributed to his training shooting turkeys in the Ozark backwoods. But even York was later to admit that most of his effective shooting had been done at a range of less than fifty yards. (McNauger, *M-16*, p. 27).

19. Almost every soldier on every front in WWII exerted every effort to obtain a fully–automatic weapon, even the much heavier and more awkward Browning.

20. The above is taken primarily from McNaughter, *M-16*. Also see Fallows, *National*

Defense, pp. 80-88. Considering the history of the M-16, the Marine Corps' recent announcement that it had "improved" the weapon with a longer barrel, longer, heavier bullets to improve accuracy, and a "three round burst" device instead of fully automatic fire "to give soldiers more opportunity to aim before they fire" (*San Francisco Chronicle*, 20 November 1982, p. 3) can only be viewed with some irony.

21. The 87:0 Israeli-vs-Syrian kill ratio of 1982 has often been cited as proving the technological superiority of U.S. aircraft flown by Israel. But others have pointed out that Syrian aircraft were two full generations behind, and that Israeli pilot training and planning may have been the most important factors in the outcome. See, for example, Luttwak *Art of War*, pp. 99-100; Epstein, *Measuring Military Power*, pp. 110-112.

22. For a contrary view, see Epstein, *Measuring Military Power*, who argues that Soviet shortcomings in training, tactics, and planning more than offset their numerical superiority.

23. Williamson Murray, *Strategy for Defeat: The Luftwaffe, 1933-1945* (Washington, D.C.: U.S. GPO, 1983).

24. Such "advanced" aircraft as the Spitfire and the famous P-51 Mustang were basically pre-war designs. The backbone of British and U.S. fighter forces early in the war consisted of Hurricanes, P-40s, and Grumman F4F Wildcats (for the Navy), all technically inferior to the aircraft of their opponents. Even by the end of the war, the Luftwaffe had far more advanced aircraft available (including the amazing Me-262 jet fighter and at least one jet bomber), although by that time neither production nor training were adequate to put more than a few in the air at a time.

25. For the particular case of military systems, see, for example: Lawrence Freedman, "The Persistence of Technological Enthusiasm: The Technological Input Into U.S. Strategic Arms Policy," *Millenium: Journal of International Studies*, 5, No. 2 (1976), 155-180.

26. See, for example, Col. Donald J. Stukel, *Technology and Arms Control*, National Security Affairs Monograph Series 78-5 (Washington D.C.: U.S. GPO, 1978).

27. See, for example, Robert A. Divine, *Eisenhower and the Cold War* (London and

New York: Oxford University Press, 1981), 36ff. Some of the more complex implications of NSC 162/2 of October 1953 were ignored in the resulting debate over the policy of nuclear "massive retaliation" as a deterrent.

28. Pierre Sprey, "The Case for Better and Cheaper Weapons" in *The Defense Reform Debate*, 193-208. Sprey also points out that P-51 prices were about half that of the more complex contemporary P-38 and P-47.

29. Production rates and cost estimates for the P-51 and F-86 taken from William D. White, *U.S. Tactical Air Power: Missions, Forces, and Costs* (Washington D.C.: Brookings, 1974), p. 47. Adjustment to constant 1983 dollars is only approximate because of variations in the several available deflators. Luttwak also notes that no current fighter could possibly be built at these rates: "at the very most, perhaps 250 of the "cheap and simple" F-16 could be built in the first year of a buildup, and not twice that number in the second year, although several hundred F-16s could easily be lost in a few days of intense fighting with the Warsaw Pact" (Luttwak, *Art of War*, p.190).

30. Congressional Budget Office, Congress of the United States, *Tactical Combat Forces of the United States Air Force: Issues and Alternatives* (Washington D.C.: CBO, 1985).

31. CBO, *Tactical Combat Forces*, op cit. But note that Luttwak's estimates (*Art of War*, p.216-217), obtained by dividing total appropriations by the number of aircraft purchased, are perhaps 50% higher than CBO figures.

32. CBO, *Tactical Combat Forces*, op cit. According to recent reports, costs for new F-16 purchases may drop appreciably due to incipient competition from the independently-developed Northrop F-20 (Wayne Biddle, "New Life for a Problem Plane", *New York Times*, 7 June 1985, p.29).

33. This is hardly disputed, and is one of the major motivations for the current "military reform movement": see, for example, White, *Tactical Air Power*; Luttwak, *The Pentagon and the Art of War*; or Sprey, "Better and Cheaper Weapons". The seminal paper of this debate, "Defense Facts of Life" prepared by Franklin C. Spinney in 1980 for the Department

of Defense, is reprinted in the Westview volume 1 (See Note 1).

34. Jacques Gansler, *The Defense Industry* (Cambridge, MA.: MIT Press, 1980), pp. 16-18, contains two remarkable charts—one showing a roughly six-fold increase in constant-dollar weapons costs from 1950 to the mid-1970s, the other a roughly ten-fold *decrease* in such consumer electronics as tape decks, televisions, and calculators. Recent declines in the cost of personal computers in general and memory chips in particular are even more dramatic.

35. See, for example, Luttwak, op. cit., p.175. But the estimate of about 30% made a few years ago by Bruce E. Armstrong, *Avionics Data for Cost Estimates,* Report P-5745-1 (Santa Monica: Rand, 1977) may now be on the low side.

36. For example, more than $2.5 million each for the M-1 tank, over $1.5 million for the Bradley armored fighting vehicle, and over $1 million each for the air-to-air Phoenix *missiles* carried by the F-14 fighter, each five to ten times the (inflation adjusted) costs of equivalent weapons used in VietNam.

37. This is the "standard" argument about Soviet development: see, for example, Robert P. Berman, *Soviet Air Power in Transition* (Washington D.C.: Brookings, 1978). Luttwak (*Art of War*) argues that this allows them to at least partially counter our lead time in development by allowing for more rapid deployment. For an interesting, if perhaps not entirely convincing counter-argument, see Epstein, *Measuring Military Power.*

38. Luttwak, *Art of War*; Also see Gansler, *The Defense Industry.*

39. The F-18 underwent so many software changes of such great extent that the airframe has been modified to fit the software rather than vice-versa. See: Jonathan Jacky, "The 'Star Wars' Defense Won't Compute", *The Atlantic Monthly,* June 1985, 18-30, at p. 26. Jacky also quotes Defense Department estimates that more than $30 billion/year, about ten percent of the defense budget, will be spent on software alone by 1990.

40. Luttwak, *Art of War,* Gansler *Defense Industry.* Few deny that complexity and reliability stand in inverse relationship. But William J. Perry, ("Fallow's Fallacies", *International*

Security, 6, No. 4 (Spring 1982), 174-182; and op. cit.) contends that complexity (measured by the number of parts) may actually decline through technical sophistication, particularly in electronics (e.g., the replacement of discrete components with integrated ones), allowing both functions and performance to increase.

41. See, for example, W. Mitchell Hoffman and Jennifer Mills Moore, eds., *Ethics and the Management of Computer Technology* (Cambridge, MA.: Oelgeschlager, Gunn & Hain, 1982).

42. This central tenet of almost every extant theory of public administration has been empirically verified through extensive case work to be true of many large private organizations as well as public ones.

43. Langdon Winner, "Mythinformation: Romantic Politics in the Computer Revolution", *Research in Philosophy & Technology, 7* (1984), 287-304.

44. In the language of science, such knowledge would have passed from the realm of theory to that of physical "law". The latter term is avoided here because of the confusion it engenders in social discourse.

45. Martin Landau and Russell Stout, jr., "To Manage is Not to Control: Or the Folly of Type II Errors", *Public Administration Review*, (March/April 1979), 148-156.

46. In a technical sense, a management control system should have as its main objective the detection and evaluation of unexpected results and other surprises. As often as not, such a system is hardly more than an upscale data manipulator with a veneer of management science.

47. Where there is no model, or no set of objectives and goals with which to compare results, the organization can hardly be said to be "managed" at all. When such organizations are large or powerful enough to have a measurable social effect they become "loose cannons"; the stronger and more serious the social forces exerted upon them, the more likely they will react powerfully (and often destructively) in another, seemingly random, direction. Unfortunately, there are examples that come to mind.

48. Landau and Stout also say that such behavior is relatively infrequent, but their argument is based largely on observations of organizations in the civil sector. Military organizations are necessarily "inefficient" users of personnel in peacetime, and such behavior is likely to be encouraged.

49. Landau and Stout, "To Manage is Not to Control", p. 153.

50. It is important to distinguish "micro-management", which seeks to prevent any possible error by assuring that all of the elements of the organization are behaving in accordance with the dominant plan, from real management, in which deviance and "error" is not only tolerated but expected.

51. Epstein, *Measuring Military Power* argues that these factors operate even more strongly for Soviet forces, propagating rigidity down the entire command structure.

52. Weinberger, *Annual Report*, op. cit. This idea is also central to the U.S. Army's "AirLand Battle" doctrine, as described in the 1982 edition of *Operations: FM100-5* (Washington, D.C.: Department of the Army, 1982). For a concise summary of a variety of technological strategies for fighting in Europe, including plans for offense-oriented "deep strike" interdiction, see: John J. Mearsheimer, "Nuclear Weapons and Deterrence in Europe," *International Security*, 9, No.2 (Winter 1984-85), 19-46.

53. Taken from the Rosemary Edmonds translation (Baltimore: Penguin, 1957).

54. Epstein, *Measuring Military Power* uses this as the basis for more formal rules for adjusting for effectiveness the numerical advantage of the Warsaw Pact forces over NATO.

55. One of the most bitter complaints about WWI was that the general staffs of all combatants held rigidly to pre-conceived plans and notions, ignoring the manifest errors of their tactics.

56. In World War II alone, some famous examples include direct interventions by Stalin and by Hitler during the critical years of 1941-1943 in Russia, and that of Eisenhower in redirecting Allied forces in the first few months after D-Day.

57. Nor is this limited to U.S. and NATO planners. See Epstein, *Measuring Military Power*, 127ff.

58. Spinney, *Defense Facts of Life* notes with some irony charts prepared by Air Force in support of the AIM-82 missile that cited calculated "air combat effectiveness analysis exchange ratios" of 955:1 for an F-15 so armed vs. a Mig-21F armed with AIM-9J Sidewinders! Even if this were true for a long series of single–plane encounters, in clear air and in isolation, it bears no relationship to the reality of multi–plane combat.

59. Luttwak, *Art of War*, attributes the persistent demand for equal apportionment of goodies among the three services to the inability of the Pentagon to make allocative decisions within the framework of the present Joint Chiefs system of administration.

60. Luttwak, *Art of War*; Fallows, *National Defense*. On the now-cancelled Sgt. York, see "A Lemon the Size of the Pentagon", *New York Times* Op-Ed, 2 October 1984; Bill Keller, "Pentagon Cancels Antiaircraft Gun: Not worth the Cost", *New York Times*, 28 August 1985.

61. See, for example, William H. Gregory, "Another Cockpit Revolution", *Aviation Week and Space Technology*, 10 December 1984, p.11, and letters in response from Richard D. Glass and Capt. George A. Fulford on 21 January, 1985 (p.134).

62. The notion of "merely competent" systems is that of H. and S. Dreyfuss (*Putting Computers in Their Place*, Macmillan, Free Press, forthcoming).

63. Karlene H. Roberts and Steven B. Sloane, "Decision-Making in Hyper-Complex Organizations: The Case of *U.S.S. Carl Vinson*", working paper, School of Business, U.C. Berkeley, Spring 1985.

64. Epstein, *Measuring Military Power*.

65. See, for example, Richard J. Debastiani, *Computers on the Battlefield: Can They Survive?*, National Security Affairs Monograph Series 83-5, (Washington D.C.: National Defense University Press, 1983).

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