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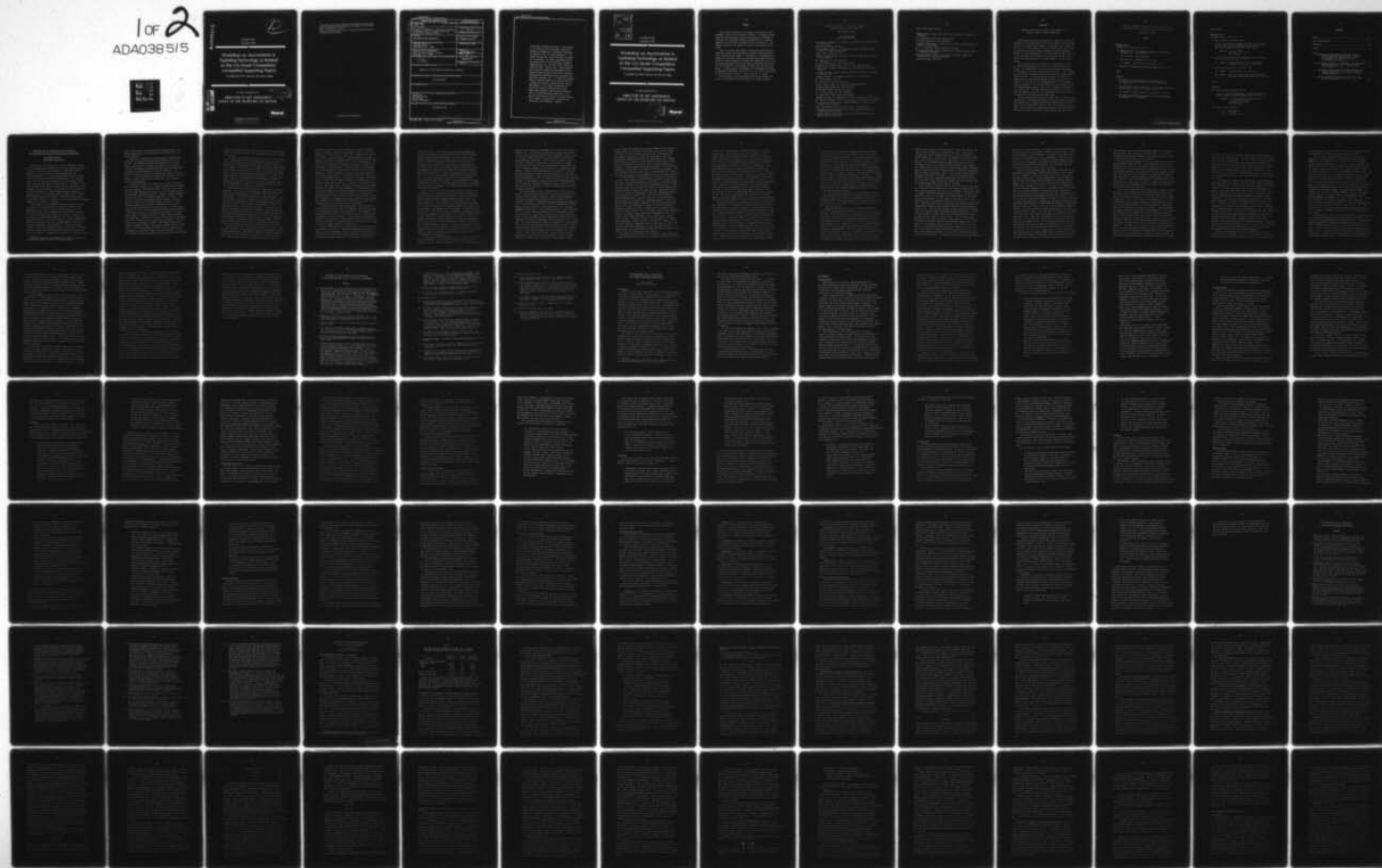
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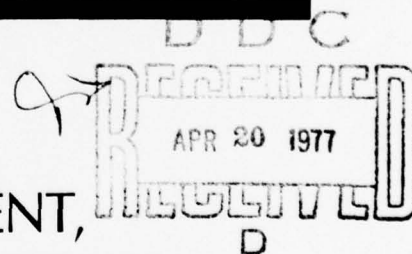
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Workshop on Asymmetries in Exploiting Technology as Related to the U.S.-Soviet Competition: Unclassified Supporting Papers

Compiled by Peter deLeon and James Digby

A report prepared for

DIRECTOR OF NET ASSESSMENT,
OFFICE OF THE SECRETARY OF DEFENSE



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The first paper discusses

The second paper examines

The third paper reports

In May 1976, The Rand Corporation, at the request of the Director of Net Assessment, sponsored a Workshop on Asymmetries in Exploiting Technology as Related to the U.S.-Soviet Competition. This report contains four unclassified papers prepared for the workshop. Dr. Robert Love discussed how the bureaucracies of three different sea powers integrated naval air into their fleets during the 1920s and 1930s. Colonel John T. Burke examined the interaction between the development of Army weapons systems and their tactical use, examining cases where new technologies were translated into battlefield systems. Dr. J. A. Stockfish proposed that war fighting capabilities could be viewed as a production function; he found that the politics and economics of the weapons development and acquisition processes undermine this notion. James Digby enumerated eight potential characteristics of precision-guided weapons that, if exploited, could greatly improve force effectiveness. (For a report on the Workshop's activities and discussions, see R-2060-NA). (Author)

The fourth paper enumerates

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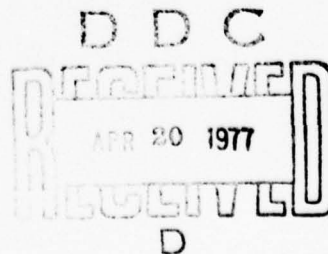
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OFFICE OF THE SECRETARY OF DEFENSE



PREFACE

This report was prepared at the request of the Director of Net Assessment, Office of the Secretary of Defense. It contains four unclassified papers prepared by various participants in a Workshop on Asymmetries in Exploiting Technology as Related to the U.S.-Soviet Competition, held in Rand's Washington Office, 18-19 May 1976. The Workshop Prospectus, the Agenda, and a List of Participants are included.

Thirty-two people participated, including experienced military commanders, present and former defense officials, research planners, Soviet specialists, and analysts. The purpose of the Workshop was to consider how the United States and the Soviet Union exploit new technology for military purposes, to examine the comparative style and effectiveness with which they do this, and to assess which factors control the efficient use of technology on either side, now and in the future. A complete report on highlights of the Workshop's activities is contained in R-2060-NA, *Asymmetries in U.S. and Soviet Exploitation of Military-Related Technology: Workshop Summary (U)*, Secret.

Views expressed in the contributed papers are the authors' own and are not necessarily shared by Rand or its research sponsors.

WORKSHOP: ASYMMETRIES IN EXPLOITING TECHNOLOGY AS
RELATED TO THE U.S.-SOVIET COMPETITION

May 18 and 19, 1976

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PROSPECTUS

WORKSHOP ON ASYMMETRIES IN EXPLOITING TECHNOLOGY AS
RELATED TO THE U.S.-SOVIET COMPETITION

The United States and the Soviet Union are engaged in a long-term competition, a competition with a fairly fixed stream of resources supporting their military establishments. If one looks at the rivalry in this way, it is clear that the efficiency with which each side converts its resources into useful military strength is of great importance. Whether it is the United States or the Soviet Union that makes best use of the technologies that develop in the next several decades will, in a major way, determine which is militarily ahead at the end of this century.

The particular task of the Workshop is to examine how each side may exploit new technology in the effort to convert resources efficiently. The Workshop will survey present and upcoming technologies on both sides and ask which are most worth exploiting. It will examine past cases where technology was quickly and efficiently used, and some where it was not. It will draw on these histories to identify the dominant factors that determine whether technology is effectively exploited. It will look at U.S. development style, at the assignment of roles and missions, at how doctrines and tactics are developed, and at other organizational aspects. Then it will consider the same matters on the Soviet side. The panel sessions will endeavor to see how the two sides compare, and what are the controlling factors with respect to efficient use on each side now and in the future.

To date little work has been done on these topics. Thus this meeting will have a pioneering role and will stress the problems of identifying relevant factors and making preliminary judgments about how well the United States and the Soviet Union are likely to use emerging technologies. To facilitate this, substantial portions of the two-day meeting have been set aside for discussion, panel meetings, and panel reports.

WORKSHOP: ASYMMETRIES IN EXPLOITING TECHNOLOGY AS RELATED
TO COMPETITION BETWEEN THE UNITED STATES AND THE SOVIET UNION

May 18 and 19, 1976

AGENDA

Tuesday, May 18

Morning (session begins at 9:00 a.m.)

1. Opening Remarks: The Long-Term Competition and Bureaucratic Impediments, *Mr. Andrew Marshall*
 - 1A. Discussion: Goals of Meeting
2. Getting the Most from PGMs, *Mr. James Digby*
 - 2A. Comment: *Admiral Worth Bagley, USN (Ret.)*
3. Technology and Modernization in Soviet Armor, *Mr. David Keener*

Lunch

Afternoon

4. Bureaucracy and the Exploitation of New Technology: The Sea Powers and Naval Aviation in the Era of Disarmament, *Dr. Robert Love*
5. New Technologies and U.S. Land Forces: Past Examples and Future Opportunities, *Colonel John T. Burke, USA (Ret.)*
 - 5A. Comment: *Brigadier General F. P. Henderson, USMC (Ret.)*
6. The Capital-Intensive Military Production Process and Perverse Incentives, *Dr. J. A. Stockfish*

AGENDA (cont'd)

Wednesday, May 19

Morning (session begins at 9:00 a.m.)

7. Panels (divided to equalize numbers)

All have the following assignment: How Well Are the Soviets Likely to Exploit the New Technologies; How Well the U.S.? What Are the Components of Efficient Exploitation?

Chairmen: *Dr. John Beling*
Ambassador Robert Komer
Mr. John Morse

8. How to Get Good Technological Ideas Through the Bureaucracy,
Brigadier General William Dunn, USAF

8A. Comment: On Presenting These Ideas to the Congress
Lieutenant Colonel John R. Pickett, USAF

9. Long-Term R&D Strategies, *Dr. Michael Landi*

9A. Comment: On Strategic Uses, *Mr. Craig Hartsell*

9B. Comment: Where the Soviets Stand on the Technologies Discussed and Their Exploitation, *Mr. Arthur Shef*

Lunch

Afternoon

10. Panels (divided to equalize numbers)

All have the following assignment: How Well Are the Soviets Likely to Exploit the New Technologies; How Well the U.S.?

Chairmen: *Dr. John Beling and Brigadier General F. P. Henderson, USMC (Ret.)*
Ambassador Robert Komer
Mr. John Morse

11. Report of panel reporters

-- *Mr. Benjamin Lambeth*
-- *Dr. D. M. Landi*
-- *Dr. S. J. Dudzinsky, Jr.*

CONTENTS

PREFACE	iii
LIST OF PARTICIPANTS	v
PROSPECTUS	vii
AGENDA	ix

Section

I. BUREAUCRACY AND THE EXPLOITATION OF NEW TECHNOLOGY: THE SEA POWERS AND NAVAL AVIATION IN THE ERA OF DISARMAMENT, Dr. Robert Wm. Love, Jr. United States Naval Academy	1
II. NEW TECHNOLOGIES AND U.S. LAND FORCES: PAST EXAMPLES AND FUTURE OPPORTUNITIES, John T. Burke, Colonel, U.S. Army (Ret.)	21
III. THE CAPITAL-INTENSIVE MILITARY PRODUCTION PROCESS AND PERVERSE INCENTIVES, J. A. Stockfisch, American Petroleum Institute	61
IV. GETTING THE MOST FROM PRECISION WEAPONS, James Digby, The Rand Corporation	125

BUREAUCRACY AND THE EXPLOITATION OF NEW TECHNOLOGY:
THE SEA POWERS AND NAVAL AVIATION IN THE ERA OF DISARMAMENT*

Dr. Robert Love, Jr.
Department of History
United States Naval Academy

Historians of naval affairs in the era of disarmament from 1919 to 1937 mostly agree that differences in military organizations proved critical in the decline in the position of British naval aviation relative to that of her rival Sea Powers, America and Japan. Clark Reynolds and E. B. Potter, eminent naval scholars who strongly differ on other issues, accept this interpretation. They especially point to the fact that from 1918 through 1937, the Admiralty lacked total control over the Royal Navy's Fleet Air Arm. Consequently, they argue, the British Navy failed to appreciate and profit from the rapid progress of the new technology. On the other hand, they maintain that both the United States and Imperial Japanese Navies, because they retained control of aviation within their traditional naval establishments, enjoyed significant advantages. Whereas the British wrongly treated naval aviation as a component of Air Power, Americans and Japanese treated it as an element of Sea Power.¹

Naval leaders of the disarmament era confronted aviation within the context of peculiar historical circumstances which merit brief examination. For a variety of rather complex reasons, two of the three Naval Powers sought to maintain the postwar status quo in 1919 but the third, Japan, sought a change in the balance of power in the Far East of an annoying and destabilizing sort. This provoked American naval officers who sat on the General Board of the Navy, a panel which advised the Secretary on war plans and shipbuilding, to conclude that Japan was "militaristic" and "aggressive."² British naval leaders concurred. Lord Jellicoe warned the Admiralty in 1919 that all evidence pointed to "Japan as the nation with which trouble might conceivably arise in the future."³ Japanese naval strategists, who hoped to rid the

* The views expressed in this paper are the author's own, and are not necessarily shared by Rand or its research sponsors.

Orient of the Occident, had long noted the restraining hand of the Western Democracies, of which they believed the United States to be the most dangerous.⁴

Therefore, one yardstick for any new military technology would be how well it measured up to the perceived needs of a war in the Far East. Most observers accepted the assumption that a conflict between Japan and one of the Western Sea Powers would be naval in character. Statesmen who believed such hostilities to be inevitable encouraged fleet preparedness, but they were a minority. The majority, who hoped to prevent a Far Eastern War, wanted to limit the means, i.e., arms, with which that struggle would be waged. As one student of the era noted, in the interwar years, arms limitation meant naval disarmament.⁵

The impulse to disarm found stimulus from a number of sources. After the German Armistice, each of the Naval Powers promptly embarked on a major program to build capital ships. These were costly plans, and the postwar depression had taken a toll in the declining revenues each government expected from taxation. Moreover, postwar disenchantment with the fruits of belligerency had begun to accelerate. These motives to limit naval arms prompted London and Tokyo to accept an American invitation in late 1921 to negotiate the matter. Of the agreements signed by the conferees in Washington early the next year, the Five Power Treaty was the most important. It set an upper common limit on total capital ship tonnage for America and Britain and allowed Japan to build up to 60 percent of this maximum. The Naval Powers agreed to a ten-year "holiday" on capital ship construction and pledged not to improve fortifications of their Pacific possessions. Each of the delegates readily concurred with a proposal to limit total aircraft carrier tonnage to 135,000 for both Britain and the United States and 81,000 for Japan. These figures comported with the overall ratio of 5:5:3 for Naval Powers.⁶ Eight years later they met again and signed the London Naval Treaty of 1930 which applied a different ratio formula to auxiliary types and extended the provisions of the 1922

Treaty for another five years. Because verification was a fairly easy matter, the signatories honored their pledges with only minor violations on all sides.⁷

The Battle of Jutland had mesmerized all navies, but the Five Power Treaty capped the ability of each to optimize the military utility of their central weapons systems, the battleship and battle cruiser. Few interwar naval chieftains would have disputed the claim of Admiral Henry Wiley, Commander in Chief of the U.S. Fleet, that "the battleship is the final arbiter of naval destiny."⁸ On the eve of the German invasion of Poland, the Chief of Naval Operations, Admiral William D. Leahy, warned Congress that the battleship remained the "backbone" of American naval power.⁹ Moreover, the Washington accords did nothing to dampen the anticipations of many that war in the Far East was inevitable. Naval officers argued that the reduction of tensions which followed ratification of the treaties was temporary and artificial.

Restrained by the Five Power Treaty from exploiting the preferred technology of the naval long gun and armored warship, the navy of each Power sought to supplement the striking power of the capital ships already afloat. They constantly improved the combat efficiency of existing battleships. Building in subordinate types proceeded with such an increased pace that the major issue of naval diplomacy during the disarmament era began to center around the displacement of cruisers. The 1930 London Treaty put caps on these programs.¹⁰ At the same time, new military technologies were exploited. By funding research and development of new submarines and aircraft carriers, for example, interwar naval establishments succeeded in thwarting the hopes of the economizers and in keeping real expenditures for naval weapons fairly high. In practice, the arms limitations agreements tended to encourage rather than discourage navies to improve their fleets by exploiting new technologies. As such, they provided an unexpected but decidedly perverse incentive.

Nonetheless, resistance to technological change was vigorous. Within each naval bureaucracy, relationships had long ago conformed to the needs of the battleship fleet. Even the most prominent and ardent proponents of aviation had to avoid challenging the supremacy of the battle line doctrine. American naval aviators, for example, based their case on the

thesis that air power would extend and amplify the range of seaborne gunnery. Obviously, anxiety over technological change involved considerations of rank and status. Naval officers emphasized that aviation was ancillary to their profession.¹¹ Aviators tended to be younger because of the demanding physical standards and since many had not undergone the normal rites of assimilation of the naval establishments, line officers often regarded their advancement as threats to careers built around service in surface ships. If aviation were to be acknowledged as tactically dominant, years invested in such service could be easily discounted. Change also animated efforts to contain the consequences. In all three navies--especially in the American and British services--the era of disarmament proved to be a period of increased centralization. In the U.S. Navy, central budgetary authority was established at a professional level within one year of the formation of the Bureau of Aeronautics. Under Admiral Beatty, First Sea Lord until 1927, the Admiralty increased its influence over the commanders at sea and the Naval Staff system was strengthened. In Japan, the authority of the Naval Staff also was revived, although this was at the expense of external restraints. Sanctions against eccentric behavior were more obvious and more successfully implemented. By comparison with other, analogous periods, however, the willingness of the interwar naval establishments to accept this new technology and all of its ramifications is remarkable.¹²

An attempt to measure relative achievement in this area involves some calibration of the tolerance each bureaucracy was willing to grant for unconventional behavior, for experimentation. The fundamental relationship between the navies' officer corps and civilian leaderships was an important factor in the equation. Political habits, constitutional traditions, and perceptions of the appropriate roles of the professional military governed these relationships which were expressed in the organizations of the higher commands of the Naval Powers.

Americans held that political authority and military power were discrete elements of government. During the disarmament era, political leaders refused to acknowledge a strong correlation between the use or availability of military power and the achievement of foreign policy aims. They frequently drew distinctions of clarity between "political" and

"military" decisions. The prevailing political ethic demanded some distance between military professionals and their civilian leadership. Moreover, the Constitutional imperative of civilian control of the military discouraged efforts to improve interservice cooperation and tended to restrict integration of the policies of the two service departments to the Cabinet level, where each was represented by the service Secretary. Thus, the prospective aegis of centralized military policymaking, the Joint Board of the Army and the Navy, never gained more than an advisory role. Attempts to coordinate policy in specific areas, such as the Joint Aeronautical Committee, were consistent failures. The highly decentralized character of the American defense establishment militated against efforts to insure uniformity and almost guaranteed a great degree of tolerance within each service for experimentation. The lateral alliances of each department with legislators also encouraged this latitude.¹³

Unlike Americans, the British believed that the use of force was so integral a part of the business of governing that they blurred distinctions between foreign and military policies. With a few exceptions, inter-war British political leaders regarded a reliance on military power as essential to the achievement of foreign policy goals. They believed that they could best satisfy their constitutional requirement of civil control of the military by integrating military and foreign policy decisionmaking at the highest levels of government. Coordination became the imperative. When an older organ, the Committee of Imperial Defence, proved to be inadequate to execute this task, the Cabinet formed the Chiefs of Staff Committee as a body subordinate to the Ministers. From this rudiment, sub-committees under the Chiefs were formed to decide policy on shared concerns, and as an arm of the Cabinet the Chiefs of Staff Committee wielded significant influence. On paper, military leaders gained greater access to civilian councils. In practice, integration of the high command increased the oversight of the military by the politicians. This relatively greater coordination meant lessened tolerance for projects lacking immediate political benefit.¹⁴

In Japan, both political and military elites served the same master. Politicians tended to accept the thesis that the use of force was an appropriate means of achieving foreign policy ends. Perfecting cooperation

among the various agencies of government involved with either became an important aim. On the Supreme War Council, the Throne, the Army and the Navy, and key Cabinet Ministries had representation. However, both the services claimed feudal loyalties within partisan politics which transcended these arrangements. These alliances allowed each force to be largely sovereign in its own realm. Naval leaders, for example, decided the mix of their force structures within the constraints of the central government's budget, but the final level of funding was seldom imposed. Instead, annual expenditures were the subject of protracted negotiations between the Cabinet and the Navy Ministry. Of the three national organizations, Japan's Navy had the greatest autonomy and freedom from centralized control. By allowing the military to solve "military" problems, the arrangement encouraged great variety of experimentation. On the other hand, conformity with norms was such a strong part of the prevailing military ethic that it tended to mitigate what was otherwise an apparent advantage.¹⁵

The American higher military command was most divorced from the process of making national security policy. This was reflected in the structures of the military bureaucracy. Within the Navy Department, authority and responsibility tended to be both fragmented and yet strangely centralized. Encapsulation probably describes this situation well. The great Bureaus, the offices of the civilian Secretary and his nominal assistant, the Chief of Naval Operations, and the sea-going commands all shared power. These relationships were so well established that it was natural that the exploitation of a new technology such as air power would to a large extent be dictated by existing bureaucratic habits. The several Bureaus had been established in 1842 to improve the management of the Shore Establishment and were satisfactory for a sailing Navy. The system weathered the squalls of agitation for a strong general staff in the Navy following the Spanish-American War in 1898. Political leaders favored decentralization since each Bureau Chief reported only to the Secretary and this seemed to assure the continuance of civilian control. Critics charged that this was a charade because the Navy Secretaries, few of whom were notably competent, lacked the technical expertise to evaluate fairly the claims of competing Bureau Chiefs.

In 1915, despite the opposition of Secretary Josephus Daniels, Congress created the Office of the Chief of Naval Operations, but the legislators failed to define his duties with great care. In practice, each CNO cemented a bureaucratic alliance with the Secretary, the first established by Admiral William Benson who became CNO in 1916. However, the Bureau Chiefs reported not to the CNO but to the Secretary, a sharp thorn in the thumb of all those who tried to centralize professional authority in the department over the next two decades. The Bureau Chiefs managed their affairs much in the manner of feudal lords, jealous of their fiefs and eager to preserve their rights. They husbanded their prerogatives with an ingenuity that would make their modern counterparts blush.¹⁶

The storm created by the establishment of the Bureau of Aeronautics on 26 July 1921 has been recorded with great precision. During the First World War, naval aviation had grown to the status of a Directorate within the Office of the CNO, a catch-all for tasks unwanted elsewhere. Benson paid little heed to his aviators, and a number of others complained that the Navy's efforts to exploit air power were lax. Admiral David Taylor, Chief of the Bureau of Construction, charged that "sluggishness" characterized postwar air policy.¹⁷ Other critics were more influential. General William Mitchell's attacks on Navy aviation induced Benson to give way and urge the creation of an additional bureau to oversee air matters within the Department. Mitchell's criticism forced other Bureau Chiefs to drop their objections to prevent all air policy from being withdrawn from Navy cognizance. A dispute arose over whether to give aviation a status similar to that of the Marine Corps, but this was beaten back by the argument framed by the powerful Commander in Chief of the Atlantic Fleet, Admiral Henry Mayo. "Any attempt to form a special Aviation Corps," he warned, "will add to the agitation for an Aviation Corps independent of either the Army or the Navy."¹⁸ Congress at this time also sought some compromise on the issue and some in the House and the Senate opposed an independent air arm on the grounds of cost. Admiral Coontz, who succeeded Benson as CNO, was eager to detach aviation from his office for reasons which remain obscure.

Rear Admiral William Moffett, who, as Director of Naval Aviation in 1920, had fought for the creation of the Bureau of Aeronautics, became

the first Chief. His was the first Bureau established in over half a century and it clearly differed from earlier arrangements. Moffett claimed authority over personnel, training, construction, supplies, design, contracting, testing, and a host of other matters relating to naval aviation. He also influenced fleet operations and shipbuilding plans. By statute, the Chief of the Bureau of Aeronautics was the principal adviser on air policy to the Secretary of the Navy. With the traditional authority of a Bureau Chief plus this added power, Moffett also tried to enlarge the functions of his office in other ways. For example, by the end of the decade the Bureau of Aeronautics assigned all naval aviators and even refused to allow the Bureau of Navigation--responsible for personnel--to inspect the records of aviators.¹⁹ More often than not, Moffett found that his bureaucratic interests paralleled those of many of his fellow Bureau Chiefs. He established lateral alliances with key Congressmen on the House Naval Affairs Committee. He fended off efforts by the CNO to gain command authority over the Bureau Chiefs instead of the coordinating function he had been granted in 1922. Moffett also struggled with the new Bureau of the Federal Budget and the Navy's Budget Officer, for both exercised great influence over naval aviation through their control of requests for appropriations.

The Imperial Japanese Navy organized naval aviation in ways which were similar to, but not imitative of, those of their American rivals. The Japanese Naval Air Service was founded in 1912 and continued as an integral part of the established naval organization throughout the Great War. Wartime operations included only seaplanes, but sufficient attention was given to the new technology that an Aeronautical Committee was created in 1916. This panel evidently coordinated the work of the agencies charged with procurement of aircraft, personnel training, and management of the naval air stations. The Japanese endured a postwar dispute between a few Army airmen and the older services over the issue of an autonomous air force, but the resolution never seems to have been in doubt. The Army and Navy claimed strong feudal loyalties within domestic politics which doomed any challenge to their authority from the start. Indeed, the Army was so powerful that it continued to control Japanese civil aviation until the end of the Second World War. Within

the Japanese Navy, the Minister was charged with overall political control, but a rival, the Chief of the Naval General Staff, often challenged the Minister's authority. Since most Navy Ministers were retired Admirals, this result was not unexpected. Control of aircraft design and procurement was given to the Technical Department of the Ministry, but a new section, the Aeronautical Department, took over most aviation functions when it opened in 1921. This reorganization preceded by a few months the arrival in Japan of the 29-member British mission headed by the Master of Semphill. They came under contract at Japanese request to organize and train Japan's naval aviators. Semphill sternly warned his hosts against establishing an independent air service on the British line, but the issue was already dead. By 1927 the Navy had given the Aeronautics Bureau a status which made the Chief a Vice Admiral, and had created a Combined Naval Air Command within the Imperial General Staff Headquarters which coordinated the activities of fleet and shore-based aviation.²⁰

While the Japanese developed naval aviation within the confines of the traditional naval bureaucracy, the British created a newer form of military organization pressed by the advocates of air power. A wartime expedient, it lasted throughout the disarmament era and relinquished only part of its control over air policy and forces at sea on the eve of World War II.

Throughout the difficult year of 1917, Prime Minister David Lloyd George expressed annoyance with the lack of a clear air policy for the Navy. By the end of the year an investigation of the procurement practices of the Royal Flying Corps and the Royal Naval Air Service revealed not only waste but also such confusion among airframe firms that production had fallen below quotas. Lloyd George appointed Field Marshal Smuts to head a committee to evaluate the problem and propose a solution. General Trenchard, Chief of the Flying Corps, urged Smuts to recommend an "amalgamated" air force, responsible for air operations both over land and with the Fleet. The objections to this idea from the Admiralty were trivial. Admiral Beatty, who had relieved Jellicoe in the Grand Fleet, doubted "there will be any grave difficulties about this provision of adequate assistance to the Navy by the new service."

Indeed, on only one point did the Navy balk: it would not turn over airplane carriers or tenders to the new Royal Air Force. Lloyd George liked the plan and his punitive nature took a fancy to Trenchard's plan to bomb German towns. In early 1918, the Prime Minister persuaded Parliament to pass an Act giving the R.A.F. responsibility over all military aviation. Both the Admiralty and the Imperial General Staff clearly believed the R.A.F. to be a temporary wartime organization and assumed that command of their air units would be returned when Germany surrendered. Aware of these expectations, Trenchard refused to disband his bureaucracy when the Armistice was signed. Within a year, the Navy sharply expressed displeasure with the state of affairs. The Sea Lords complained that Trenchard's devotion to long-range bombing meant that naval aviation had been discounted. These protests went unanswered and little was done until Earl Beatty became First Sea Lord later in the year.

Beatty decided to recapture Fleet Air Arm shortly after taking office, but he held back from strong protest to the current arrangement until 1922, when Trenchard announced a plan to cut back the number of squadrons assigned to the Navy. The Admiralty raised objections not only to the specifics of the plan but cited it as an example of the general disability under which naval aviation operated. The Sea Lords most objected to the fact that they had no voice in design specifications for new aircraft to go out to the Fleet. Winston Churchill tried to bring Beatty and Trenchard together on common ground by proposing that the Navy "should have full and unfettered control over ... aircraft while employed for naval purposes" but insisting that the Air Ministry remain "the supreme professional authority on aerial warfare as a whole." Beatty replied that the Navy should be allowed "to say what they want, order it, and pay for it." He did, however, admit that the Air Force could continue to be responsible for the "actual supply of aircraft to the Navy," thus avoiding the dreaded "competition in the markets." Lord Trenchard rejected this idea. He rested his case on "the unity of air" and maintained that all that was needed was "the real good will" of the Admiralty to make inter-service cooperation a reality. The fall of Lloyd George's government a few days later forestalled any prompt resolution of this conflict. The immediate political crisis notwithstanding,

the result was largely inevitable. The Cabinet found the wrangling to be petty and treated it as an annoyance rather than a major concern. The Admiralty's demands lacked the urgency of an overseas flareup which might have provided the backdrop for serious consideration. Moreover, the conclusion of the naval limitation treaties at Washington opened up a new dawn of hope for disarmament, within which the dispute between the R.A.F. and the Navy seemed churlish and outdated. The new Cabinet under the Tories told both sides to muffle their discontent.

Within a few short months, however, the brouhaha broke into the open again and the Prime Minister, Stanley Baldwin, appointed Lord Salisbury to chair a committee to resolve the issue of the control of air forces operating with the Fleet. After a promising start, the Sub-Committee on Aviation under Arthur Balfour became distracted by newspaper campaigns mounted by allies of both sides and by charges, mutually exchanged, of leaking secret information to the press. The force of the Admiralty's case was spent when a dangerous spat with the French erupted and concern within the government shifted to building up the R.A.F. Home Defence Force to protect Britain against French bombing raids. Meanwhile, Beatty and Trenchard prepared lengthy papers restating their respective positions in detail. Balfour's Sub-Committee conceded a few points to the Navy but largely favored the R.A.F., arguing that the Fleet Air Arm should remain within the Air Ministry. Balfour based his conclusion on Trenchard's theory of the unity of the air. The full Salisbury Committee agreed with Balfour's report, but encouraged a firm accord between the two services on several specific issues. In the spring of 1924 Trenchard and the Deputy Chief of the Naval Staff, Admiral Roger Keyes, met frequently together to negotiate a truce. Their final paper marked the close of the Admiralty's early effort to recapture Fleet Air Arm and a notable bureaucratic victory given the odds against success. The Trenchard-Keyes Agreement provided that the Navy could state the number and characteristics of the aircraft it wanted but left final design specifications and actual procurement of the aircraft to the Air Force. A signal change in command was achieved when Trenchard gave in to Keyes' demand that air squadrons operating from carriers would be under the operational control of the ships' captains. In addition, up to 70 percent of the R.A.F. personnel employed in the

Fleet would be drawn from the Navy, although during their "attachment" to the Air Ministry they would receive Air Force ranks. On the issue of training, Trenchard remained obdurate. The Air Ministry retained final responsibility for training all naval aviators.²¹

The Trenchard-Keyes Agreement served as the basis for relations between the Admiralty and the R.A.F. through the remaining years of the disarmament era. There were some gradual changes, but the contention that the unity of the air dictated certain essentials of military organization usually prevailed. The thesis was never truly disputed by the Sea Lords until the crisis of 1934-1935 when, under Admiral Ernle Chatfield, they began to mount a vigorous campaign to regain complete control over naval aviation. In 1937, an Assistant Chief of Naval Staff for Air was appointed, and, in that year, the process of transfer began that was completed on the eve of belligerency by which the whole of seaborne aviation was given over to the Royal Navy.

In fine, both the United States and Japan chose to allow, for different reasons, their traditional naval establishments to supervise naval aviation but found it necessary to create new and small staffs, responsible for most facets of air policy. On the other hand, Britain decided to hand over one part of naval aviation, the airborne part, to a new combined military aviation agency, although the traditional naval bureaucracy retained some influence over selected air matters. Other factors enter into any estimate of the success or failure of these arrangements. For example, during the first decade of the disarmament era, the Japanese were building up their airframe and ancillary industries, whereas the United States and Great Britain ended the First World War with several firms fully qualified to fill postwar orders. Indeed, one of the strongest complaints of American airplane companies during the decade centered on the failure of the Army and the Navy to exploit their plant and skilled manpower.²² The Japanese scoured Europe for better aircraft during the 1920s, the Navy buying planes from Britain, France, and Germany. As the Depression neared, the Japanese increasingly began to secure licenses to build aircraft of European design in factories in the Home Islands. By the time the Army invaded Manchuria, the Imperial Navy could rely almost

solely on aircraft produced in Japan. While Japanese firms continued to imitate the best Western designs, they seem to have been willing to experiment with their own improvements. To a certain extent, this may have been due to the fact that the Zaibatsu, the great industrial combines which dominated Japanese manufacturing, quickly carved up the military aircraft business and no real competition remained after about 1922-1923. The absence of true competition meant that the Navy often received an inferior product, but it often also allowed the larger firms to test new innovations with some assurance that the contract would always return an adequate profit.

In all probability, a major cause of the British lag which developed around 1927-1928 was the inability of the Naval Air Section of the Admiralty to influence the Air Staff on issues of design. Communications between the Fleet--or the user--and the aircraft firms was discontinuous. In America, on the other hand, Moffett kept in close touch with his aviators. He had no authority over fleet operations, but he could quickly translate the lessons derived from naval air operations at sea into contract requirements. Once naval aviation joined the Japanese Fleet, the same prompt transmission of technical knowledge seems to have occurred. The case of landing gear provides a good example of this contrast. American and Japanese naval aviators copied a British scheme to attach a landing hook to the undercarriage of the aircraft which would catch a wire stretched athwartships on the deck of the carrier as it touched down. They ordered aircraft which had their undercarriages strengthened to stand the shock of these "controlled crashes." The Fleet Air Arm was fully aware of the potential of this system, but the Admiralty could not force the Air Ministry to order aircraft unsuited for land-based operations. Consequently, the British lost about 10 years of practice in the use of the more advanced and relatively simple system, being forced to turn to it only in 1930 when airspeeds had made alternative systems unworkable.²³

Another contrast suggests that the unique British organization of aviation probably contributed to her loss of naval superiority. All navies controlled the design and specifications for their aircraft carriers and,

in the disarmament era, none seems to have achieved any particular advantage during any of the three phases through which each passed.

The first phase of the development of the aircraft carrier was "experimental" and was inaugurated by the British with the conversion of HERMES, EAGLE, and ARGUS. Into this category fell the second HERMES, the first ship built from hull up as a carrier. Shortly thereafter, the Americans converted a collier into LANGLEY, while the Japanese launched the conversion, HOSHO, in late 1921. All were small carriers: HOSHO, for example, displaced only 7470 tons and HERMES about 3500 tons more. The British, who enjoyed an early lead, hoped to build more and at the Washington Conference Admiralty representatives obtained an agreement under which each Naval Power would be allowed to convert two capital ships into carriers and still remain within the limits set by the Five Power Treaty. This second generation of "treaty carriers" included the American LEXINGTON and SARATOGA, both made over from battle cruiser hulls which otherwise would have been scrapped; the Japanese AKAGI and AMAGI, also cruiser hulls, the latter of which was damaged in the Tokyo earthquake and had to be replaced by KAGA, formerly a battleship hull; and the British COURAGEOUS and GLORIOUS, also cruiser conversions. All of these ships displaced at least twice the tonnage of their predecessors. In fact, the Japanese and American carriers all exceeded the maxima provided by the Treaty and each Navy was forced to hide their true size. This second generation of carriers allowed each Naval Power, after about 1927-1928, to attempt to integrate air operations into the scouting forces of their fleets.

The third phase of aircraft carrier development was closely tied to the Five Power Treaty limitations and in each navy produced discussions over how the remaining tonnage allowances should best be used. For example, the combined displacement of LEXINGTON and SARATOGA was roughly half of the total of 135,000 tons which the United States could build within Treaty limits. Similar constrictions faced the British and Japanese naval staffs. Within each navy a dispute broke out between those who favored building a large number of small carriers and the proponents of programs emphasizing a small number of larger carriers. After considerable effort, Moffett

persuaded the General Board to alter the provisions of a previous directive and announce in 1927 that the United States would build a small carrier. Congress delayed construction for two years, but the result of Moffett's endeavor was instantly dismissed as being too small. RANGER displaced only about 14,500 tons, and was viewed by Navy airmen as inadequate for protracted operations in the Pacific. WASP, laid down after Moffett's death, simply used up the tonnage left to the United States under the Five Power Treaty.

By 1931, the Admiralty had arrived at the same conclusion as had Admiral Moffett: a large number of small carriers meant that a lower percentage of the carrier striking force could be sunk in a single attack. Oddly, Trenchard's preachments about the utility of bombing moving ships had influenced the Sea Lords, who felt that larger carriers also made larger targets for land-based aircraft. However, when the Admiralty proposed building a number of small carriers in 1931, the government of Ramsey MacDonald refused on the grounds of economy and the program was shelved. When the next carrier was laid down four years later, the retirement of ARGUS meant that any ship under 20,000 tons would put Britain under the carrier tonnage allowed by the Treaty. Thus, the Admiralty specified that the ARK ROYAL should displace slightly more than 22,000 tons upon launching. The Japanese also turned to a third generation of small carriers with RYUJO, which displaced only 10,600, but by the time she joined the Combined Fleet Japan had decided to seek parity with the other Naval Powers or abandon the disarmament system. Moreover, fleet operations during the Shanghai crisis of 1932 convinced the Naval General Staff that Japan needed larger carriers. In the waning years of the disarmament era Americans and their naval counterparts in London arrived at similar conclusions.

After 1933-1934, the attention of British military planners shifted from Japan to Europe and the rise of Hitler. Struggling to get out of the Depression and faced with a new and more potent threat, the British felt unable to maintain their earlier lead in aircraft carriers. While the United States and Japan continued to build up their naval forces in preparation for a war in the Pacific, the Admiralty was locked in bureaucratic battle with the Royal Air Force over annual estimates. The Anglo-

German Naval Treaty of 1935 seemed to promise perpetual British superiority over a possible German surface fleet. The agreement induced a false sense of security among political leaders, as did the Admiralty's claim two years later that the use of asdic, or sonar, could easily check another German U-boat offensive. Moreover, British political leaders feared the growing strength of the Luftwaffe more than Hitler's Navy. While the Admiralty finally regained control over the administration of Fleet Air Arm in 1937-1939, the British Navy could still not operate any land-based patrol planes.²⁴ In the United States, the Army Air Corps and the Navy wrangled over roles and missions with the latter usually besting the former because of the support of the Navy-minded President, Franklin D. Roosevelt. Not until 1938 did American military strategists begin to view Germany as a possible enemy, but the two large naval authorizations passed by Congress in 1940 still aimed at building a fleet to fight in the Pacific.²⁵ Only the onset of American belligerency altered this trend. The Japanese, on the other hand, had only one maritime front. Although the Army after 1937 was bogged down on the Chinese mainland, the Navy General Staff continued to look to the east and prepare accordingly. More than anything else, these politico-strategic factors lost the British their early dominance and allowed American and Japanese naval leaders to exploit naval aviation most successfully. Given British indifference to antisubmarine operations before the outbreak of the Second World War, these disparities comported with strategic priorities.

In conclusion, the Treaty system provided the greatest incentive for all of the Naval Powers to exploit new maritime technologies to destabilize a balance of power that each nation perceived to be artificial and disadvantageous. By contrast with the American and Japanese military organizations, British military bureaucracy offered greater opportunities for those unsympathetic to naval aviation to exercise checks on experimental activity. The Imperial Japanese Navy exercised political leverage unavailable to its counterparts in Great Britain or the United States but American naval aviators achieved the greatest degree of autonomy by accepting severe restrictions on their voice in national security policy planning. The fact that the British decided to divide control over naval aviation

between the Air Force and the Royal Navy worked to the disadvantage of the proponents of the new technology. Nonetheless, other factors were more important in dooming the lead in this system that the British enjoyed for several years after the Armistice of 1918. The breakdown of the Treaty system in the early 1930s and the rise of a new Continental threat shifted British attention away from the Far East. The need to develop long-range, carrier-based striking power lessened. Furthermore, the Admiralty viewed the advent of aircraft and submarines with alarm. British sea power in the ages of sail and coal rested on the control of chokepoints, but the new technologies, even in their infancy, threatened this traditional margin of supremacy. Even during the 1920s, disinclination tended to shadow policy. However, American naval officers in the era of disarmament increasingly viewed naval aviation as one means of overcoming the inferiority they believed the Five Power Treaty had imposed on the United States. Likewise, leaders of the Navy of Japan, as the period of peace drew to a close, agreed that their exploitation of this new technology promised a military solution to their older political problems.

BUREAUCRACY OF THE EXPLOITATION OF NEW TECHNOLOGY:
THE SEA POWERS AND NAVAL AVIATION IN THE ERA OF DISARMAMENT

Endnotes

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NEW TECHNOLOGIES AND U.S. LAND FORCES:
PAST EXAMPLES AND FUTURE OPPORTUNITIES*

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THE PROBLEM

That the United States cannot hope to match the Soviets' quantitative advantage in military power is a basic precept of U.S. defense planning. The numerical imbalance being an unalterable reality, we look to technology for salvation, reasoning that qualitatively superior combat systems, the product of an advanced industrial base, and sophisticated management techniques will at least fill the gap. Considering existing asymmetries between the two forces it seems clear that, regardless of what might have been, this offset has not been achieved. The Army of 1976 is, in many important ways, not greatly different from the Army of 1945. Where meaningful progress has been made, notably in nuclear munitions, airmobility, guided missilery, and the like, it is matched in Soviet achievements, or in no way closes the net gap in land combat power. It is natural, even inevitable, that the Soviets exhibit superiority in selected technologies and systems. But, as we shall see, their quantitative advantage is now coupled with qualitative advantage in many key land combat systems.

The paradox is that technology is, and has been, advancing at an exponential rate, and the United States has demonstrated a unique ability to apply its benefits whenever government or industry chose to do so, whether in massive, integrated efforts such as the space program, or in broad areas of homogeneous technology such as solid-state electronics, automation, and chemical plastics. Yet critical military research and development programs costing billions of dollars were aborted or produced equipment far behind the requirement and the state of the art, sometimes decades after program initiation. Obviously, if

* The views expressed in this paper are the author's own, and are not necessarily shared by Rand or its research sponsors.

the initial assumption of technological superiority was correct, and surely it was, something went seriously wrong.

The shortfall must be viewed within the context of a remarkably turbulent period, one characterized by virtually no continuity in technology R&D. First there was the exhaustion and military apathy following World War II, then an expenditure of billions to rebuild Europe and Japan. There was the unanticipated Korean War, the Berlin blockade and Cuban missile episodes, the exorbitant demands of the Vietnam conflict, and influences of the Arab-Israeli mideast wars. An early strategic policy of massive retaliation had a major impact, along with the belated shift to emphasis on conventional land combat power. The space program devoured resources, though it also provided valuable technological spinoffs. Enormous sums were spent on foreign economic and military aid, again with both benefits and penalties. The periodic crises too often generated knee-jerk reaction and shift of priorities at the expense of what should have been consistent technological objectives. Meanwhile, technology was moving so rapidly that systems were sometimes obsolete at the time of delivery. The conditions called for shrewd selectivity and long-term persistence, which, no matter how logical in hindsight, proved extremely difficult to implement.

The central questions now are apparent: Is the original assumption of the 1950's valid in 1976--that the United States can establish an acceptable balance in land combat power via technological superiority? Should we not assume that Soviet progress will continue, that sequential crises affecting U.S. progress will occur in the future as they have in the past? Is circumstance the culprit, along with the very nature of the U.S. political system, or is it a matter of built-in, artificial obstructions that can and must be removed?

To explore the matter we will review developments applicable to selected battle systems over the past three decades or so, try to identify the dynamics at work, and from these derive ways in which the United States might attain a genuine technological advantage.

THE EXAMPLES

The Battle Tank¹

Deficiencies in U.S. land force combat developments are in many cases attributable to defective perception, planning, and stated or implied policy rather than to technology per se. This appears to be the case in tank development, judging from past and present asymmetries in U.S. and Soviet progress.

Design differences in the U.S. M60A1 and the Soviet generational counterpart, the T62, reflect striking differences in implied (a) tactical technique, (b) attitude about crew survival and related human factor engineering, and (c) the balance between quality and quantity. Main armament capabilities are about equal at ranges of 1200 meters or less; in long-range engagements, the M60A1 is superior, largely because of precise ranging and fire control. Ballistic design and silhouette of the T62 are probably the world's finest (it is about one meter lower than the M60A1), and the Soviet tank is more nimble. The T62, however, is fire-prone and much more susceptible to catastrophic destruction because of external fuel tanks, inferior armor plate, and (though there is some disagreement about this) a magnesium alloy engine housing. The U.S. tank has a much roomier turret and carries more main gun ammunition of greater variety.

These differences are not simply the product of technical tradition or design accident, but rather reflect basic differences in tactical perception and economic choice. The Soviets rely on the synergism of massed tanks in the short-range engagement and reduction in hit probability by the combination of low silhouette, excellent ballistic design, speed, and mass. U.S. tank designs emphasize tank and crew survival as well as precise, long-range gunnery, considerations that mean fewer tanks for given dollar resources, but not necessarily a net advantage in tank survivability. What's more, technological trends would seem to favor the Soviet attitude on balance. Terminally guided antitank missiles, not to mention more advanced precision weaponry of

the near future, will not only supply the long-range attack capability but greatly increase tank attrition at all ranges, and do this in spite of protective shielding. Another major factor is the compression of battle time--short, furious engagements provide little opportunity for tank retrieval and repair, a process in which the U.S. has invested much more money and manpower than have the Soviets.

The United States has a reputation in some quarters as the "world's worst tank designer," and, in historical perspective, the reputation seems well-deserved. In view of the enormous dollar resources, time, and effort the Army has expended on tank development since the early 1950's one could reasonably expect that by 1976 U.S. land forces would be equipped with either a technically superior battle tank or at least one on technical par with those of Soviet and other forces and in competitive quantities. Yet, over the years, U.S. tanks have lagged many others in qualitative design (e.g., many armor experts consider the M60A1 to be inferior to both the British Chieftain and the German Leopard). First there was the World War II Sherman, greatly inferior to the German Panther and Tiger. Then came the T95, a so-called "medium/heavy" tank that (fortunately) never achieved series production and was an early sign of what many consider an illogical obsession with armor shielding and crew protection at the expense of mobility. There followed during the 1950's a parade of models and modifications--M46, M47, M48, M41A1, M48A2, and finally the basic M60 and M60A1. Series progress was limited primarily to up-gunning (76mm to 90mm to 105mm), as well as some advances in fire control, armor shielding, mobility, and, in the case of the M60, in the diesel engine/transmission power pack. Meanwhile the Soviets relied upon three basic models--the celebrated T34 of World War II (which the United States encountered in both Korea and Vietnam), the T54/T55 series, and the T62 discussed above.

An intense, costly, and time-consuming effort to build a truly advanced tank, initially as a joint U.S./German effort, was aborted in 1971 on the basis that it was too sophisticated at too great a unit cost.² A presumably less costly substitute, the XM-1, will emerge from

the competition of two U.S. prototypes during 1976, followed by comparative competition with an advanced German Leopard; neither would be available in the field for several years. To complicate the matter, the Soviets are now moving into series production of a new battle tank, the T72, and beginning to phase out the T62. This, as reported to the Senate Armed Services Committee, has "serious implications to U.S. defense planning."³

Analysis of these events suggests questions such as the following:

- o Why did the United States adopt what seems to be a series of "shotgun" programs, rather than hold steady on a single interim model (possibly based on more advanced foreign technology) with minor modifications insofar as they offered meaningful improvement at reasonable cost, and meanwhile engage in a carefully considered, long-range program to field a truly advanced battle tank?
- o To what extent did the "arsenal syndrome," the urge to perpetuate an in-house design and production capability, influence tank concepts and programs? A prevailing view in Army Ordnance was that the tank is so uniquely military that civilian industry had little to contribute, except perhaps in engine and power train technology. Yet, some well-qualified observers express confidence in the XM-1 program precisely because of the role of civilian industry in the undertaking.
- o Why did Army, the Defense Department, and the Congress pursue an adversary attitude regarding the MBT-70 program, one resulting in enormous losses in both time and money? While the million-dollar unit cost came as something of a shock to some members of Congress, the developmental program was by no means a secret to the Government community in general.

- o Why is there a confusion between requirements, technology, and doctrine? The alleviation of this problem depends upon a clearer Army statement toward both doctrine and technology, the development of imaginative but realistic programs in which all concerned can have confidence, and the clear, unambiguous articulation of requirements. We are now committed to the XM-1, which, judging by preliminary indications, will be an excellent system. Follow-on or complementary systems are another matter. Even the armor community is divided in its view of the future--the impact of precision missiles as well as sensor mines and other antitank threats, the potential of light, inexpensive, highly mobile, small fighting vehicles armed with advanced sensor-guided ordnance, the essential requirement to adapt to logistic realities by a quantum reduction in ammunition quantities, and the distinct possibility of practical remotely guided robot weapon systems. So can we capitalize on these potentials in spite of the drag of "sunk costs"?
- o To what extent has the U.S. approach to tank development been influenced by the presumed doctrine (actually a slogan) that "the best defense against a tank is another tank"?⁴ This might well explain our concentration on an extended range gun capability, as well as on protective shielding, since it encourages the view of armor battle as a "one-on-one" engagement rather than maneuver. Paradoxically, maneuver has long been fundamental to our armor doctrine, the concept being to envelop and deploy against weakness, to avoid when possible the tank-on-tank engagement, and to strike with massed formations against the enemy flanks and rear. Technology, and specifically high performance infantry weapons, lend additional logic to this concept. Yet, in

practice, both U.S. tank design and deployment (i.e., in NATO plans are essentially geared to a combination of localized counterattack and the one-on-one gun engagement.

Antitank Systems⁵

The basic technology for terminally guided missiles was available as early as 1945. The German Ruhrstahl air-to-air missile, which was still under development at the close of World War II, is believed to be the inspiration for the French SS-10 antitank missile system fielded in the mid-1950's. The SS-10 was followed by the SS-11, a greatly improved version, which the U.S. adopted.

Surely the advantages of guided missiles over guns and rockets, at least for long-range engagements, was clear enough. Why was the United States, and for that matter many other nations, so slow to produce viable systems? It was not entirely for lack of trying, as indicated by the U.S. effort with the DART vehicle-mounted missile as early as 1952-1958, a program cancelled at a cost of about \$40 million when the product proved so unreliable and otherwise unacceptable as to require complete re-design. Of interest is the vignette supplied by a senior retired officer involving the SHILELLAGH. He was greatly impressed by the potential of the SHILELLAGH as an advanced heat-seeker missile as early as the mid-1950's, and urged the then-Chief of Army Research and Development to give its development high priority, which the latter promised to do. The Ordnance Corps, however, was determined to give SHILELLAGH a dual, gun/missile configuration, and also produced a very delicate, unreliable mount, the M551 SHERIDAN tank. Thus, a superb early recognition of what was later applied as TOW technology was evident in the mid-1950's, but was not established as a formal program until 1959, nor delivered to the field until 1965, and has been cursed by troops in the field ever after--at least until its latest "overhaul."⁶

Some sources state that the United States deliberately bought the French SS-11 and ENTAC systems to avoid hasty development of still new

technology and to allow for initial observation of existing systems. Perhaps so, but it hardly explains the opportunity lost. Many are of the opinion that TOW could have been fielded long before it was, and that the United States by now should be well on its way to development of much more advanced systems. What's more, a serious void in short-range antitank capability was revealed during both the Korean and Vietnam Wars; shortcomings of both the 3.5 in. rocket launcher and the M72 LAW cannot be explained as just "poor discipline and training," at least according to highly qualified professionals who personally engaged the Soviet light T46 and medium T34 tanks.⁷

That the Soviets took a more productive approach seems clear. During the 1950's, they relied much more than Western nations on antitank guns, had little use for the recoilless rifle approach, and relied upon the RPG-2 rocket launcher for short range. The latter was followed by the formidable RPG-7, a considerable advance over the RPG-2 by virtue of a sequential rocket principle that provides good range as well as relatively high accuracy since it has a flat trajectory and an excellent hollow-charged warhead that reportedly penetrates about 23 centimeters of armor. Soviet antitank missiles appeared at about the same time as the French SS-11, first the SNAPPER, then the SWATTER (which apparently is still something of a mystery) and finally, about 1965, the SAGGER that proved so effective during the 1973 Arab-Israeli War.

One gets the impression that U.S. developers tended to look at tank and antitank technology as separate elements, rather than as parts of a dynamic interface. Major efforts were made to upgrade tank shielding and armament while antitank technology lagged, yet it was becoming increasingly clear, starting in the early 1950's, that probabilities favored advances in relatively cheap antitank missiles and warheads over improvements in tank shielding.

As for the future, the next quantum advance in antitank weaponry is most likely a family of terminal rocket systems linked to accurate,

real-time target acquisition and/or relying on the "fire and forget" principle. The United States is working slowly in this direction (e.g., with the cannon-launched guided projectile [CLGP] and HELLFIRE). A capability for target destruction at long range from the vertical, rather than horizontal, aspect would in effect blur the distinction between "direct" and "indirect" fire; providing it can be done routinely (as opposed to "special purpose"), this would mean a revolutionary change in tank-antitank dynamics.

Artillery

The most obvious characteristic of today's "tube" artillery is that it represents little change in World War II (and even earlier) technology--apart from the organization and fire direction systems--except insofar as pieces are mounted on armor-protected, tracked mounts.⁸ The self-propelled concept itself is of more significance than armor carriage technology, and in this respect two points are worth noting:

- o In recent decades the United States has emphasized the armor-shielded, self-propelled mode as essential to mobility and crew survivability in the mechanized environment. Conversely, and despite their mechanized orientation, the Soviets have employed towed artillery. This asymmetry has sparked many an Army study, most of which concluded (a) that the Soviets simply relied on massed artillery echeloned in depth rather than fire unit survivability, (b) that the Soviet advantage in cheap manpower is a factor, and (c) that their "situation" is different, operating as they are on the Eurasian land mass and on internal supply lines. Now the Soviets are deploying self-propelled artillery, presumably in large quantities. Apparently neither technology nor tactics was the answer, but simply resource priorities.

- o It should be noted that while the United States had armored, self-propelled artillery, it had no infantry fighting vehicles and the Soviets did. It seems paradoxical that while the United States was content to move infantry forward in armored carriers, then dismount it to fight on foot, the same logic did not apply to the less exposed (though still vulnerable) artilleryman. The comparison is not exact, of course, but it does reflect the doctrinal attitude that infantry is a close, personal combat element while tanks and artillery naturally avoid "physical" contact and engage by stand-off fire. The effect of this rationale is evident in later discussions of infantry fighting vehicles.

Technology's gift to artillery thus far has been in the form of increased range and lethality of warheads--the former, for instance, in the rocket-assisted projectile (RAP) and the latter in improved conventional munitions (ICM) having far greater destructive effects than the standard artillery round. Automated fire direction (TACFIRE), properly used and with adequate manual backup, greatly facilitates artillery responsiveness. Yet, on the whole these are marginal improvements in standard capabilities, which doubtless the Soviets can match and possibly better. In no way are they a quantum advance in long-range point or area effects, at least not with "conventional" as distinguished from nuclear munitions. A genuine leap in capabilities would be dependent on: (a) the technologies that can provide precise target acquisition, identification, and "fixing," along with a real-time communication link to delivery systems; (b) high performance terminally guided munitions, including designs that are independent of an external designator requirement (in other words, are truly independent "fire and forget" munitions); and (c) rocket-like propulsion characteristics that permit delivery by a family of inexpensive, highly mobile launchers. Many Army development analysts, including

experienced artillerymen, are of the opinion that the on-going CLGP effort is not the correct approach, unless it is viewed only as an experimental, special purpose system.⁹ For one thing, the missile must withstand very large G-forces as it emerges from the rifled tube. For another, even if the development is successful, in the sense that it produces a pinpoint hit capability, it in effect becomes simply an augmentation to existing artillery guns and ammunition inventories. Apparently CLGP is inspired primarily by concern over "sunk costs" in existing hardware, which in the past has frequently thwarted promising technologies. As for rockets, the Army dismantled its free flight rocket capability following World War II, and, unlike the Soviets and most other armies, saw rockets as too crude in range and accuracy to be worth the investment. Only recently, based on further study of the matter, has Army decided to develop a General Support Rocket System (GSRS) and field a blend of tube and rocket artillery. Whether this might be the prelude to a viable precision (terminally guided) rocket system remains to be seen.

Why so much attention has been given to artillery range capability while limitations in target acquisition detract seriously from its value is difficult to understand. The Army Combat Development Command conducted numerous very detailed studies of artillery dynamics and requirements, but never generated an integrated approach to the application of advanced technologies. Yet such an approach is the only realistic hope for a qualitative advantage.

Armored Fighting Vehicles

Two new systems of this category are entering the Soviet inventory in increasing numbers: The airborne amphibious armored combat vehicle (BMD) and an amphibious armored infantry combat vehicle (BMP). Both systems fire antitank guided missiles, reportedly of very advanced design. The United States has only recently chosen a contractor for its Mechanized Infantry Combat Vehicle (MICV). The MICV will presumably be armed with a 25mm automatic cannon (BUSHMASTER), but the Army has

yet to decide between two prototypes for this weapon, and will have to equip the initial production MICV with an interim weapon system.¹⁰

This represents a very important asymmetry between U.S. and Soviet force structures and fighting concepts. The Soviets long ago emphasized the value of mounted, armor-protected, fighting infantry, a concept that recognizes the need for infantry (to supplement tank) "shock effects," as well as the ever-increasing lethality of the modern battlefield. The United States has been content to field no more than an armored carrier (currently the M113) for the forward transport of infantry, then rely upon dismounted infantry for the assault. This obviously is a vital difference in tactical perception, not technology. Notwithstanding its poor record in tank design, the United States certainly has had the capability to design an integrated infantry fighting vehicle had it chosen to do so. Of course, earlier development of advanced antitank missilery and automatic cannon might have helped the concept along. There are complaints in some quarters that even the new MICV is essentially the old "iron box" concept with mounted cannon, or perhaps TOW, instead of a machine gun.

While dollar resources are always a factor, this does not explain the striking difference in U.S. and Soviet concepts. One sees in the Soviet attitude something akin to Brigadier General F. P. Henderson's proposition that infantry has gained very little from technology despite the obvious potentials for converting unrewarding close combat into a stand-off fighting capability.¹¹ If one puts great store by such doctrinal slogans as "close with the enemy," "seize the high ground," and the "balanced squad is eleven men" (or some other fixed number), then one is inclined to develop armored trucks rather than high performance infantry fighting vehicles. The fact is that during the period under review the Army spent huge sums on some seven models of common cargo trucks, each providing a marginal benefit in capability but otherwise complicating the maintenance and fuel problem. The 1972 tactical vehicle study (named WHEELS) shows not only qualitative but enormous quantitative proliferation of common vehicles in the Army

inventory of the time. In this and many other instances, the allocation, and not simply availability, of resources indicates a distortion of priorities.

Unfortunate experiences with several other developmental programs not only consumed valuable resources but most likely dampened enthusiasm for combat vehicle experimentation. A notable example is the M551 SHERIDAN reconnaissance vehicle mentioned previously. Still another is the M114 scout vehicle, which is essentially a thin-skinned machine-gun-equipped runabout, mechanically unreliable and gravitationally unstable. One might also reflect on the earlier M59 personnel carrier, the one that replaced the half-track and featured synchronized engines that habitually failed to synchronize, as well as the M151-1/4-ton "jeep," which has been an unreliable and somewhat dangerous vehicle from the beginning.

Looking to the future, it seems apparent that the survivability and overall viability of infantry must be of paramount concern. Granting that infantry, by definition, will always have to engage in the dirty, close-combat, high attrition environment, surely the objective must be to minimize such engagements to the extent that both technology and tactical concepts will permit. Technology--notably precision, terminally guided weapons, the increasing value of small fighting vehicles, and extremely lethal warheads--suggests that the traditional combat arm distinctions are no longer meaningful. Armor, artillery, and infantry tend to blend in fighting mode and tactical technique, and only within that context can one project future combat development programs.

Surface-to-Surface Missiles

For some 15 years U.S. programs were heavily influenced by a strategic concept of massive retaliation, a concept prompted by the Soviets' advantage in conventional combat power, as well as U.S. nuclear superiority.¹² The Army viewed tactical nuclear strikes as the logical extension of strategic policy and, therefore, both money and technology were concentrated on tactical nuclear delivery means.

Hence the development of costly surface-to-surface missile systems (SSM): The early long-range CORPORAL, HONEST JOHN (20 nautical miles), SERGEANT (75 nautical miles), and PERSHING (400 miles) for the very long range. Complementing these were short-range rocket systems, the LITTLE JOHN and DAVY CROCKETT, as well as the 280mm artillery gun. In 1963 the Army began the development of LANCE, a system designed for a much higher rate of fire and much more mobility than SERGEANT and LITTLE JOHN, which it was intended to replace. LANCE, however, did not go into service until 1973.

While perception improves remarkably with hindsight, several aspects of the SSM objective are difficult to understand:

- o The "conventional" warhead feature of the systems is essentially a fringe benefit, not a basic rationale. In fact, these systems were built to provide a surface-delivered nuclear strike capability, functions that can to a large extent be furnished by both air and naval platforms. Roles and missions aside, many analysts were (and are) of the opinion that Army should expend its dollars and energies on more "natural" ground force battle systems.
- o Distant target surveillance and acquisition were, and are, extremely difficult functions. Such systems as PERSHING, SERGEANT, and LANCE employ inertial guidance, which, technical accuracy aside, depends upon precise data as to both target and delivery system location. Thus, the utility of these systems for the delivery of nonnuclear ordnance in particular is highly questionable--unless, that is, they become the delivery vehicle for precision delivery of multiple sub-munitions. Otherwise, such missiles are surely the most expensive possible method of target attack from land platforms.

To the extent that the Army does pursue advanced application of existing SSM systems (the PERSHING II concept as a first step, for instance), difficult decisions remain in terms of the optimum benefits and related priorities.¹³ Assuming that one cannot fund both long-range and shorter-range applications (although basic technological research would in many respects apply to both), and in recognition of the fundamental requirement for target acquisition and a reliable signal link, would it not be best to concentrate in near and mid-range capabilities, rather than targets at beyond fifty miles, for instance? The important evaluation is of the total, closed-loop performance--acquisition, precise delivery, and counter-measure resistance.¹⁴

- o The rather sorry history of LANCE development is of special significance because it is replete with technical failures and delays as reflected in the ten-year development and re-design period. As late as 1972 the destiny of LANCE as a "conventional" system was the subject of heated debate. Considering the potential for perfection of the "precision loop," however, it may be that LANCE's future is much brighter than its past.

Air Defense

Even a cursory comparison of U.S. and Soviet air defense situations reveals serious asymmetries, to the latter's advantage.¹⁵ A capsule history of selected U.S. systems is instructive:

- o NIKE-HERCULES: This has been the Army's main high-altitude air defense system since 1958. A major modification program (SAMCAP) began in 1972, the objectives being to improve missile maneuverability and resistance to electronic jamming until SAM-D became available in "the late 1970's." Keeping NIKE-HERCULES in the field is an expensive proposition because

some components had to be redesigned and remanufactured as supplies of spares ran out.

- o The low-medium altitude HAWK has been in service since 1960, and, while very costly, it is one of the most widely used air defense systems in the world. An improvement program began in 1964 to provide a larger warhead, a new guidance mechanism, an improved solid propellant, and additional counter-counter-measure features. But the improved HAWK was not released for full production until 1972, some seven years later. Originally towed by standard Army trucks, some HAWK units are now self-propelled.
- o CHAPARRAL is the Navy's air-to-air infrared seeker missile adapted to ground launch, and was originally intended to be an "interim" system, pending development of a more advanced LOFAAD (low altitude, forward-area air defense system). Just recently the Army chose the German ROLAND II for this role, and is already finding costs to be much greater than expected, ostensibly because unexpected design modifications are required.

The Soviets have assembled an integrated, quite sophisticated family of surface-to-air systems: the high-altitude SA-2, counterpart to the NIKE-HERCULES; the medium and low-level track-mounted SA-4 and SA-6; two recent systems, the self-contained SA-8 and SA-9, both mounted on lightly armored, wheeled amphibious vehicles; and, of particular significance, the Soviet ZSU-23-4 radar-directed gun system. The net value of these systems, as well demonstrated in the 1973 Arab-Israeli conflict, is the synergistic effect of the interfacing high and low altitude capabilities. Thus, while reportedly the SA-2 (being susceptible to chaff and jamming) accounted for few Israeli plane losses, the SA-6, a mach 2.8 integral rocket ramjet, extracted a heavy toll, as did the ZSU-23-4, when aircraft were driven down to its low-level envelope.

SAM-D is intended to be the Army's all-around antiaircraft weapon of the 1980's (originally the 1970's), and its chronology, too, is instructive. Formal statement of the requirement goes back to 1964 and the development came under project management in 1965. High costs and technical risks had killed the earlier MAULER effort. SAM-D was flown eight times during the advanced development period 1967-1972, and began subsequent full-scale development in February 1972. After this considerable "gestation" period, the advanced system intended to replace the 15-20 year old NIKE-HERCULES and HAWK systems is now under "austere development."¹⁶

As with other systems, it is difficult to compare U.S. and Soviet progress in terms of resource allocations, and it is reasonable to assume that the Soviets, like the United States, experienced many design/developmental failures. Still, considering the U.S. technological advantage in the 1950's and 1960's, notably in electronics, it seems clear that the air defense gap should be attributed to factors other than technology as such:

- o Definition of a SAM-D requirement in 1964, followed by considerable achievements, if not "breakthroughs," in the 1960's and 1970's, yet we find a vital system still under "austere development" as late as 1976.
- o Costly modification programs to "fill the gap"--the NIKE SAMCAP program beginning in 1972, and a modification of HAWK, though begun in 1964, not fielded until 1972.
- o A difference in perception, as indicated by the Soviets' development of highly mobile, track-mounted systems while HAWK was until recently pulled by a truck. Perhaps the rationale was (a) economy, and (b) a sufficiency of roads in Europe. In any event, the Soviets took a broader view.

Army in-house problems aside, one must look to more fundamental influences if hindsight is to be useful:

- o The original concept of an advanced, high performance SAM-D air defense system was correct, and had it been vigorously pursued as a national objective, recognized as such by both the Defense Department and the Congress, SAM-D would be well advanced, probably already fielded. However, development procrastination, failure to define requirements, and ever-increasing costs have subverted the SAM-D program.
- o Air defense should have been viewed at the outset as a family of mobile, integrated systems. Perhaps it was in the abstract (SAM-D does fit this view), but the "shotgun" approach indicates that the concept was not shared and supported at the national level.

Air Mobility¹⁷

The paradox in this area is that helicopter technology and airmobile doctrine and organizations developed so slowly despite the early enthusiasm of Army aviation experts. The Army-Air Force conflict over roles and missions was a serious obstacle, of course. Still, it is reasonable to speculate as to why the air mobile potential was not recognized early on as a national objective and treated as such. Thus, despite the confidence and enthusiasm of not only Army experts but such renowned pioneers as Sikorsky, U.S. defense planners were content to let Service differences, rather than technological and tactical potentials, rule.¹⁸

The long struggle to advance airmobile concepts is well known within the professional community and will not be detailed here. Briefly, it involved formally imposed restrictions on helicopter weight and roles, along with other obstacles that severely hampered both helicopter technology and employment until the 1962-1965 period.

Progress during the Vietnam conflict, while considerable in terms of organizational concepts and tactical techniques, was relatively little in terms of helicopter technology. There was an imaginative use of "bailing wire" techniques such as the attachment of weapons to the workhorse "HUEY" vehicle, and, of course, the evolution of one integrated system, the COBRA gunship. Development from zero base, so to speak, of a truly advanced fighter helicopter began during the 1960's, but Congress rejected the resulting proposal, a \$2.5 million unit cost CHEYENNE. Of interest is the unsolicited effort of the helicopter industry to develop a less costly version such as the Sikorsky BLACKHORSE, which early displayed quite impressive speed and mobility. Army has now lowered its sights to a lighter, less sophisticated, and far less costly version than the CHEYENNE, to be chosen from a competitive run-off.

A brief word on the heavy lift helicopter is in order. Some 25 years ago the Soviets held the world record for helicopter payload/speed combination. Yet, in 1976 the Army cancelled its heavy lift helicopter program as too costly relative to other material requirements.

To this writer, at least, several conclusions seem proper:

- o In helicopter technology the United States lags well behind what was entirely possible by this date. The advantages of (a) visionary concepts at a very early time, and (b) an excellent technological base coupled with a competent helicopter industry were dissipated by the failure to establish long-range, realistic goals in an area of great promise.
- o Quite apart from inter-service disputes, many Army people obstructed helicopter and airmobile progress, ostensibly because they questioned its tactical viability, but, at least subconsciously, they saw the prospects as a threat to their traditional branch roles.

- o Too little attention was given to the implications of the quantity/quality ratio. Thus, regardless of the merits of a high-performance system such as CHEYENNE, its unit cost would limit distribution to the extent that its contribution to overall combat power was questionable. In effect, the program envisioned a heavily armed and armored vehicle providing what, by analogy, is the shock effect of armor. This seems to be an extension of the reasoning that produced large, heavily armored tanks rather than small, light ones in greater quantity, and depending upon mobility and low silhouette for survival. Enhanced helicopter maneuverability is now a prime objective.

Logistics

The most obvious facts of logistics are that U.S. land forces have not yet made more than marginal improvements in logistic land mobility, and that the transportation, storage, security, and timely delivery of ammunition are by far the greatest challenges. What is discouraging is the huge investment in a family of cargo vehicles that provide not much greater haul capability than was available during World War II, and that relatively little progress has been made with technology that might provide meaningful progress, such as air cushion techniques.

High intensity combat today consumes a truly monumental amount of artillery and other ammunition, as reflected in consumption rates in World War II, Korea, and Vietnam. One had only to watch the logistical operations in Vietnam, particularly the miles of highly vulnerable low-boys winding into the hills, each loaded by back-breaking labor and unloaded in similar fashion, to realize that for logistics time literally stood still.¹⁹ It is extremely difficult to conceive of operations of this nature in mid- or high-intensity conflicts of the future. Even if it could be accomplished despite ever-growing

threats to sea and aerial transport, the manpower requirements and supply losses would most likely be exorbitant.

The traditional attitudes about logistics are themselves serious obstacles. The doctrinal concept that "logistics supports the operation," even when logistic considerations should, logically, govern the choice of tactical options, is very harmful. So is the notion that one can habitually employ massed artillery fires, which directly contradicts trends in technology that favor interdiction over supply. Among the rationales for precision weaponry is the "fringe benefit" of reduced munitions requirements, but even more compelling is the distinct possibility that neither adequate ammunition nor the capability to deliver it will be available.

Logistics might well prove to be the Achilles heel of Soviet operations, in that their doctrine apparently envisions a quick war in recognition of, among other things, the vulnerability of stores and supply lines. If the assault can be slowed by the rapid attrition inflicted by precision systems, and if those same precision systems demolish supply points and supply columns alike, that doctrine would lose its attraction.

SOME CONCLUSIONS

The conclusions suggested by these comparisons must be qualified in important respects: First, classified systems and technology are excluded--such areas as nuclear, chemical, high energy laser, smooth-bore weaponry, and cruise missile technology--comparative analysis of which could weigh heavily in the verdict, not only in a net assessment, but in evaluating the rationale for resource priorities. Second, emphasis in this paper has been on net results in a variety of systems, rather than step-by-step developments in a few. Nevertheless, the history reflects a wide gap between technological potentials and U.S. land force capabilities, and suggests certain corollary or alternate conclusions as to why this gap exists:

- o Both choice of systems and technological emphases were heavily influenced by the sequential crises typical of the era, as well as by major, fundamental changes in U.S. strategic concepts and tactical perceptions flowing from those concepts. Hence, Army developments, such as the battle tank, became piecemeal, "shot-gun" affairs, rather than methodical applications of technology toward longer-term objectives.
- o The military let-down following World War II created a five-year or more lag in the land force posture, which (a) explains to an extent the failure to capitalize on advanced technology, such as the German Ruhrstahl missile; and (b) prompted a leap to regain momentum to the detriment of methodical progress.
- o Within the context of the 1950-1960 era an immediate tactical nuclear capability was considered essential. While no doubt influenced by parochial considerations (namely, that this was an Army, not air or naval, mission), the ground forces had little faith in the reliability of such alternatives, particularly for close-in nuclear strikes. Hence, the urgent and costly effort was initiated to develop land-based, including long-range, missile delivery systems. Whether or not resources allocated to such systems would have been approved for programs to achieve genuine "breakthroughs" in such seemingly mundane items as tanks, infantry fighting vehicles, and artillery, or for that matter the then visionary items of high technological risk such as terminal homing missiles, is quite another matter. Probably not.
- o The inflexibility of budget mechanics ensured that a program in motion remained in motion, even when technical failure or emerging priorities called for program termination. Also, since resources were tied to mission packages, misgivings

about a program might jeopardize the entire fund allocation and were therefore not likely to be expressed. Army enthusiasm for the anti-ballistic missile project doubtless would have waned early if that \$4 billion, or a major part of it, could have been applied to other land combat requirements.

- o Total Army resources are so limited, relative to both those of other services and valid requirements (a situation now made worse by growing personnel costs) that flexibility in resource allocations to various developmental needs is extremely limited, and an error in either system choice or developmental technique and costs is greatly magnified. Thus, of some \$6.4 billion involved in military program cancellations between World War II and 1964, only about \$700 million was applied to Army programs, of which \$200 million was for MAULER alone. Yet that \$700 million had a far greater proportionate impact on the Army than did the much larger cancellations on the other services.
- o Because of this ratio, Department of the Army and the Congress tend to take a more jaundiced view of the Army's technical failures. This has been a serious stumbling block in defending the SAM-D air defense system, as well as the XM-803 battle tank and the CHEYENNE attack helicopter, and would be regardless of the technical feasibility or tactical logic for those systems.

The conclusions thus far, if valid, would explain in large measure the technical deficiencies and imbalance in land force system developments. Still, they do not entirely explain what seems to be a poor "return on investment" on Army R&D funds. Nor do they entirely account for perceptions that neglected important aspects of tactical and technological evolution.

The "genuine" return on R&D investment should be measured in terms of developmental equipment that is subsequently fielded, and that

contributes materially to increased combat power. In this sense, the Army return on investment is not good, apart from the aforementioned factors, evidently because of:

- o Excessively ambitious efforts to produce optimum equipment, in the sense of incremental sophistication that greatly increased technological risks yet offered only a marginal bonus in system capability or in what the same resources could otherwise have provided. The DART missile is in this category.
- o The "patchwork" approach to correcting system deficiencies. While initial technical problems are a natural by-product of advanced technology, it is difficult to rationalize the long and troublesome history of such equipment as the SHERIDAN M551 reconnaissance vehicle and the LANCE surface-to-surface missile system. In both cases technicians treated the individual symptoms rather than engage in a wholesale recuperation effort.
- o Unrealistic testing. SHERIDAN, for instance, was evidently tested in a "hygienic" environment, with too little consideration for field realities.
- o In some cases the land forces could have "made do" with equipment on hand rather than enter new developments, notably in support equipment such as trucks. There were many new models of standard equipment that provided little or no advantage over the old, features like multi-fuel engines and automatic transmissions being of questionable merit, not to mention proliferation of model types.
- o Force structure designs tended to follow old practices regardless of actual requirements, the result being a quantitative proliferation of such items as tactical trucks and radios. In these particular cases the excess was determined by much later analyses.

- o Visionary but unrealistic ventures that absorbed too much in resources and effort relative to their potential cost-effectiveness or the state of the art. The OTTER land train and the GOER articulated cargo vehicle seem to fit this category. Conversely, the Army has failed thus far to fully capitalize on technology with real technological potential for overcoming the twin forces of gravity and friction, such as air cushion power systems and vehicles.
- o A fragmented, cumbersome, parochially oriented, and transitory (in terms of personnel tenure) combat development/R&D structure and, corollary thereto, little focalized expertise.
- o The tendency to gear both program choices and developmental methodology to the "in-house" capability, whether in terms of U.S. technology or the Army arsenal complex. Even such events as procurement of the French SS-11 antitank missile was more of a desperation move than an exercise in objectivity, considering parallel efforts with the DART missile.

COMBAT DEVELOPMENTS

Around 1972 the Army Combat Development Command produced a two-part study entitled "Land Combat System (LCS) I and II." Part I was focused on the near term, and Part II on the period 1990 and beyond. The conclusions and recommendations were a considerable departure from traditional land combat doctrine and tactical concepts and, in contrast to the usual Army approach, visualized a dynamic integration of new technology with revolutionary force structures. The study suffered certain shortcomings, such as a tendency to ambiguity and circular logic, but nevertheless represented an important change in approach. In any event, LCS evoked no more than cursory attention

by the Department of the Army (one analyst tagged it as "nothing but a wish list") and, when last heard of, LCS rested in the "basis for additional study" file.

Such was the fate of the Army's only known effort to project a "grand design" for its developmental requirements, unless the Training and Doctrine Command has resurrected the effort. In the absence of a projected grand design, Army systems have, as a rule, been the product of recognized technology, applied essentially as "improvements" to standard equipment within the framework of existing tactical concepts and doctrine. Several factors tend to encourage and perpetuate this approach, one being the sheer complexity of grappling with the implications of rapidly advancing technology. Another is the impact of "sunk costs" in existing materiel, since even if the Army were to change direction it would have to be done gradually, a process requiring duplicate and incremental resources that the Army could not possibly support within its established budget program, and that neither the Defense Department nor the Congress would be likely to approve. A brief historical review provides some insight into the matter.

During the post-World War II years the Army relied on a very fragmented developmental structure, elements of which were Continental Army Command (CONARC) and its branch-oriented agencies (e.g., the Infantry and Armor Boards); the Chiefs of Technical Service, who had both Army special staff status and supervisory authority over the arsenal complex; and, at Army General Staff level, the Deputy Chief of Staff for Operations and the Assistant Chief of Staff for Force Development. Not unnaturally, this organization tended to perpetuate traditional, branch-oriented concepts. Also, while theoretically CONARC and the principal overseas command expressed the users' requirements, in practice the Chiefs of Technical Service exercised great, sometimes predominant, influence over equipment design and production priorities.

In the early 1960's technical service functions were consolidated into a central structure, the Army Materiel Command (AMC), while Combat

Development Command (CDC) was assigned the central function of recommending systems and force structures, becoming in effect the user's representative under the staff "cognizance" of the Assistant Chief of Staff for Force Development. While this was an improvement, the fact is that AMC was usually more influential than CDC, at least in terms of developmental priorities and progress, and frequently channeled technology along routes of its own choosing. Much of the CDC work was imaginative and otherwise useful, but was seriously impaired by excessive analysis. Nor was CDC alone. Quite frequently recommendations forwarded by CDC were subjected to repetitive "review" at Army and Defense staff levels, then revised for "further review" under entirely different guidelines. Such treatment was almost habitual if the proposals entailed noticeable increases in either personnel or materiel requirements, which they usually did.

The CDC structure eventually became entirely too large, with too many offices assigned to review and administration, namely at field agency, intermediate group, and headquarters levels. Just how this was expected to produce timely, imaginative, and definitive solutions is not, in retrospect, clear.

There were other obstacles, such as an unwarranted confidence in computer-driven output, with too little regard for the source or ambiguity of the input. Another handicap was the "proof syndrome," namely, an insistence upon detailed, mathematical or empirical demonstration if a proposal was particularly challenging. An anecdote illustrates the point: In about 1971 a young officer at lower agency level was assigned the task of re-evaluating the requirement for the extended range artillery (RAP) round, the project being under heavy attack on a cost-effectiveness basis. His initial analysis stated that an objective mathematical evaluation was not possible for lack of meaningful target structure and acquisition data. One year and three versions later he continued to insist that target acquisition was fundamental to target attack, that acquisition data were still missing, that artillery had all it could do to fix the short-range targets,

and that under existing conditions RAP should be viewed as an experimental and special-purpose requirement if priorities permitted. He suggested, with considerable logic, that meanwhile Army would do well to put its money on target surveillance and acquisition.

THE APPROACH-AVOIDANCE CONFLICT

What is frequently lacking in Army program recommendations is an aggressive (albeit well-balanced) confidence in requirements for both individual systems and the program as a whole, together with a united service position. To an extent this reflects what for lack of better terminology one might call a "technology neurosis," a perception that technology on the one hand offers great, even revolutionary opportunities for increased combat power, but on the other poses very high technical and monetary risks. The decades have been marked by too many disappointments and frustrations of realizing that the potentials somehow seem to escape. This creates a sort of approach-avoidance complex, the perception that no matter how attractive the potential, caution is the better part of valor. Automation and sensor mines and barriers, for instance, could prove of enormous value, but derision of the systems as so much exotic gadgetry is not uncommon.

In effect, much of the Army community is now gun-shy. Perhaps this explains, at least to an extent, why there is not more appreciation for the possibilities in precision weaponry. By its very nature this technology implies the need for different doctrinal attitudes and entirely different battle systems. But the design and decisionmaking process can be very painful, hence the tendency to adhere to the old tried and true.

As of 1976 the Army is painted in a corner, so to speak, by virtue of a few very costly programs no matter how valid and vital, that will consume such a huge slice of the budget pie that relatively little is left after personnel costs for more than very limited, austere new developments. Yet, somehow the Army must convince the Defense Department

and the Congress that technology can provide what is otherwise impossible, and that costly new initiatives must be supported as a national effort.

PROPOSITIONS FOR THE FUTURE

Without a doubt the United States could attain a quantum leap in combat power--within a decade if not sooner--by concentrated, selective employment of its enormous technological capabilities. This prognosis, however, is meaningless if attitudes and procedures are merely an extension of those of the past three decades.

Internal shortcoming aside, the Army has for too long been the "poor man" of the armed forces, severely hampered by unrealistic resource constraints, not to mention program turbulence that makes methodical development impossible. Nothing in the paper is meant to suggest that the Army itself was in practical control of its developmental destiny. The inflexibility of budget procedure, for instance, and the policy of linking acquisitions and missions to funding "packages" prompted the Army to perpetuate programs of questionable value, even after circumstances had altered the initial requirement, rather than run the risk of losing the entire fund allocation. The Army must be given a more adequate share of defense resources, and it must be given the flexibility to reprogram funds as conditions dictate, provided that basic objectives are well defined.

What is also needed is a change of perspective, at the national as well as Army level, along with a set of guidelines for which the following propositions might serve as a starting point:

Proposition 1: The present Soviet advantage and developmental momentum is such that the United States can achieve an acceptable balance in land combat power only by adopting extraordinary measures. Technological potentials are such that an exponential leap in land combat power can be achieved within five to seven years, providing it is supported as a national priority.

Proposition 2: The primary obstacles to fulfillment of Proposition 1 are (a) delayed choice from among the multitude of existing and potential technological opportunities; (b) indecision fostered by skepticism, reluctance, and parochial and political influences. It is possible to minimize the effects of these factors, but only if major changes are made in the developmental approach.

Proposition 3: Attainment of the objective requires acceptance of formidable technological risks. The approach must be to define these risks at the outset, and concentrate on the early, intense testing of sub-technologies.

Proposition 4: Programs must advance on an established schedule regardless of intervening political and military events. If progress is aborted by shifting objectives and priorities it will be impossible to attain an exponential advance, regardless of the merits of interim achievements.

Proposition 5: Exponential progress depends upon full use of interfacing technologies, present and anticipated. The present dependence upon a cooperative exchange of data should be replaced by a mandated pooling system, focused on a clear definition of national technological objectives. A technology "alert" network, aimed at foreign (including Soviet) as well as U.S. technology is a natural corollary of this proposition.

Proposition 6: National policy must mandate a focusing of talent and dollar resources on those selected technologies (a) in which the United States has the greatest present and potential advantage, and (b) in which breakthroughs offer the greatest potential for a quantum advance in qualitative land combat power.

Proposition 7: Marginal improvements in standard system designs will not, alone or in combination, contribute materially to the objective as stated, and such programs should be entered only in special cases. Conversely, the "building block" principle, whereby a

capability can be greatly enhanced by attaching an advanced sub-element to an existing system, will sometimes offer great potential.

Proposition 8: Small groups of innovative individuals with broad military experience are much more likely to produce conceptual breakthroughs in applied military technology, as well as relate new technology to optimum tactical organizations and techniques, than is the formal combat development structure. Simulations and other automated tools, while invaluable as sorting and iteration devices, are of little, sometimes negative, value in arriving at advanced concepts.

Proposition 9: Positive encouragement and support of Army efforts is basic to fulfillment of Proposition 1. Conversely, the burden of presenting bold, imaginative programs having high probabilities for overall success regardless of interim risks rests with the Army community.

Proposition 10: Apropos of Proposition 6, it is unlikely that more than a marginal and very gradual increase in the Army's net combat power can be achieved within present budget and program constraints. Requirements for established, still essential developmental programs, such as the "Big Five," along with fixed operating requirements, leaves little for parallel developments of major consequence.

The Logic of "Deliberate Asymmetry"

Proposition 1 speaks of achieving "an acceptable balance in land combat power." The definition of "acceptable balance" is not easy, but the objective seems more realistic than "closing the gap," which in a sense implies a mirror-image effort to erase asymmetries and try for a match in quantitative capability. Surely the U.S. goal must be to foster deliberate asymmetries between U.S. and Soviet combat systems and tactical employment concepts; design structures capable of inflicting quick, simultaneous, multiple-attrition; avoid or minimize the localized, short-range engagement, particularly by massed formations that can only lead to unacceptable personnel and system attrition; then move into the exploitation by a synergistic integration of precision

firepower, high mobility, and surprise. Such an approach gives new dimensions to the fundamental principles of war, interpretations implicit in technological trends. "Mass," for instance, is not a physical conjunction, but rather the discrete, precise, simultaneous application of firepower coupled with vertical and horizontal mobility. "Surprise" is the utter unpredictability of when or where one will suffer sudden system attrition. Quantum reductions in ammunition consumption as well as the mobility and intense combat power of small elements are classic applications of "economy of force."

What was once a pipedream is now technically possible and pragmatically feasible. A recent paper by John H. Morse stresses the revolutionary implications of rapidly advancing technologies that furnish more destructive energy in smaller packages, quantum increases in warhead delivery speed, vastly improved mobility and communications, and enhanced ability to destroy quickly whatever can be located.²⁰ He acknowledges the challenge of target acquisition, as has this paper; but that, too, can be met with innovative advanced technology. (Remotely piloted vehicles, for instance, are not only weapon platforms but offer dramatically new dimensions to battlefield surveillance.) Morse, too, is less than sanguine about real-world prospects because, as he says, "any suggestion for significant changes in military systems or thought always raises a host of questions and leads inevitably to a series of investigations whose effect is often to study new proposals to death, thus preventing or interminably delaying their adoption."

James Digby of The Rand Corporation has covered the implications of precision-guided munitions (PGMs) in some detail, with emphasis on priorities, risks, and opportunities.²¹ While describing the revolutionary potentials, he quite correctly stresses the present limitations of PGM-related technologies, as well as the numerous, formidable obstacles to progress. In consideration of our past performance in handling (even less sophisticated) technology, Proposition 2 herein would appear to have high prophetic value. The

choices and interfaces are so numerous and complex that both the analytical tasks and practical decisions are vulnerable to interminable procrastination, not to mention wrong choices, and thus a drastic change in developmental methodology is called for. Paradoxically, one can make a strong case that the most obvious objectives and the simplest methods are likely to be the best.

Neither the present configuration of the U.S. Army nor its developmental program fits what we have defined as "the logic of deliberate asymmetry." Neither can we adopt it without major changes in weaponry, tactical and support concepts, and doctrine. If one accepts the rather common attitudes that (a) the technology, whether or not possible, has not yet been proved; (b) sunk costs in present programs, as well as the momentum of on-going developments, are so great that new programs are infeasible; and (c) that in any event it is unrealistic to expect quantum change, except possibly over a period of several decades, then Propositions 1 and 2 are violated at the outset. It is even more unrealistic, however, to believe that, short of a catastrophic event (when it will be too late), national priorities will permit the matching of Soviet momentum with traditional force structures.

Fundamental to the proposed, asymmetrical approach is what we define here as the "precision loop," a closed system of launchers, terminally guided projectiles, target acquisition systems, and integrated counter-measure resistors. Evaluation of such systems as a primary tactical mode will show them to be completely in harmony with the classic principles of war, but also that they call for entirely new tactical perceptions:²²

- o A target hit depends upon neither human observation nor projectile velocity, hence the distinction between "direct" and "indirect" fire would tend to lose significance.

- o Terrain configuration, while still relevant, takes on entirely different significance. High ground, for instance, owes its importance to the observation it affords, its value for cover and concealment, and its channelization effect. But if observation and accurate fire are relatively independent of terrain, the objective of "seizing the high ground," historically so very costly in lives and lost momentum, will lose its rationale.
- o One could depend upon a family of relatively inexpensive launchers, mass-produced and fielded in large quantities, blended into organizations that blur the distinction between "infantry" and "artillery" modes. This in turn would permit the concentration of funds and quality control on the projectile, and on the target acquisition-guidance loop. The implications to strategic and tactical mobility are apparent.

What seriously hampers acceptance of such concepts is the possibility that the Soviets, with their demonstrated technological competence and persistence, would field comparable forces and thus neutralize any advantage. Also, the Soviets might be willing to expend the resources necessary for a dual conventional/precision capability, while the United States gambled everything on new technology and revolutionary force structures. Actually, the value of alternative structures is a function of conceptual validity, lead-time, and system quality, to include counter-measure capabilities. With sufficient confidence and aggressiveness, the United States could seize an insurmountable advantage. What's more, the Soviets cannot easily shift the momentum of their present effort, nor is it likely that the monolithic Soviet structure, its advantages notwithstanding, can adopt revolutionary change as well as could the United States, assuming of course the national will to do so. The United States has overcome the early Soviet lead in space, despite their early Sputnik satellite and an intense concentration of effort.

In any event, it is quite evident that the capabilities to find and destroy are rapidly exceeding the capabilities to hide and protect, and there is every reason to believe that this trend will continue. The great future opportunity, therefore, is to not only bend with the wind but to harness its power. It seems to be the only rational way.

NEW TECHNOLOGIES AND U.S. LAND FORCES:
PAST EXAMPLES AND FUTURE OPPORTUNITIES

Endnotes

1. General J.H. Polk, "We Need a New Tank," *Army*, June 1972. An important analysis of the U.S. tank situation from the viewpoint of one of the Army's most experienced armor officers, including comparison of the Soviet T62 and U.S. M60A1.
2. Ibid. General Polk refers to demise of the MBT-70 as "the latest act in this tragedy of errors." Concerning the missile-firing M60A2 he states, "In 1966...I recommended that we cut our losses and drop this particular product but was overruled because the sunk costs were too high and, besides, the problems could be 'fixed.' We are still fixing them, and the sunk costs have doubled."
3. *Hearings Before the Committee on Armed Services, United States Senate*, 94th Congress, 2nd Session on S.2065, Part 1, January 29, 1976, Statement of the Chairman, JCS, p. 53.
4. The infantryman habitually views the tank as his defense against enemy tanks. For instance, in an article entitled "Give Me a Tank" (*Army*, November 1972), Lt. Col. A. N. Garland says: "The old line infantryman wants something that will stop armor cold at ranges up to 2000 meters, not something that might work at 20 meters. I know what they claim for the current antitank weapons. But I pity the poor 'grunt' who must depend on them. And the issued flak vest is not made to ward off 105mm high-velocity rounds."
5. The chronology and system details in this paragraph are based largely on John Weeks, *Men Against Tanks--A History of Anti-Tank Warfare* (Mason/Charter Publishers, Inc., 1975).
6. According to Mark Stewart in "Army R&D Should Pay Off--But Hasn't" (*Armed Forces Journal International*, August 1975), "Sheridan still experiences such poor mechanical reliability that many an armored cavalryman wishes he was astride his old M41. So does more than one foreign country who still implore the Army to reopen the M41 production line while none have procured Sheridan."
7. B. F. Halloran, "Soviet Armor Comes to Vietnam," *Army*, August 1972. Halloran recounts an attack on a Special Forces outpost in Vietnam (1968) and states that of a mix of 106mm recoilless rifles, 57mm RR, and M72 LAW's, only the 106mm's were effective, even against the Soviet PT 76 light tank.

8. It is true, however, that by increasing the propellant charge as well as fragmentation effect of the standard artillery projectile 105mm artillery of today has about the capability of 155mm artillery of World War II. According to an Army Colonel who personally observed operations in the 1973 Sinai war the Israelis consider U.S. artillery fragmentation superior to that of the Soviets.
9. Of interest in this respect is an article by Brig. Gen. A. R. Toffler and Maj. R. B. Miller entitled "Artillery Punch" (*Army*, November 1973) in which they advance the hypothesis that a blend of CLGP and standard artillery would be more cost-effective than an alternate composition of antitank missiles and other systems. What the article seems to neglect, however, is (a) the possibility that rockets, not CLGP, are best; and (b) the implications of precision counter-battery by opposing forces. The article is nevertheless a valuable basis for further analysis.
10. *Hearings Before the Committee on Armed Services*, (op. cit.), p. 143. The Chairman's JCS report also points out the importance of the Soviets' BMD and BMP infantry fighting vehicles.
11. Brig. Gen. F. P. Henderson, "The FMF, An Alternate Future and How to Get There," *Marine Corps Gazette*, July 1971. He states: "While training manuals may extol the virtues of 'eyeball to eyeball' combat and the 'spirit of the bayonet,' their audience has always thought there must be a better and less tricky way to eliminate the opponent." He quotes Ardant du Picq: "To fight from a distance is instinctive in man. From the first day he has worked to this end, and he continues to do so." Henderson envisions an entirely different combat force, the Marine Search and Attack Battalion, a combination of command, search and target acquisition, infantry search and attack, air search and attack, target attack, combat service support, and attached elements.
12. See J. S. Tompkins, *The Weapons of World War III* (Doubleday & Co., 1965). Tompkins charges that the United States lags far behind in weaponry essential to a flexible war policy because of its "absolute reliance on an inflexible nuclear policy." While debatable in many respects, the work provides numerous valuable insights into developmental obstacles, including the American affection for sophistication, program fragmentation, flawed strategic and tactical perspectives, parochialism, traditionalism, bureaucracy, and frequent failure to grasp the implication of available technology.

13. Pershing II is an interesting example of the interaction of technology, strategy, and international political dynamics. It is quite evident that technology is closing the gap between nuclear and "conventional" effects, which, paradoxically, is viewed in some quarters as a serious threat to military stabilization. H. T. Simmons, in an article titled "Pershing II" (*Army*, August 1974), cites the need to verify radar area correlation (RADAG) technology, and goes on to say: "But the (Senate Armed Services) Committee's main objection did not appear to be any of these. What seemed most troublesome was the concept of a highly accurate, low yield weapon which might actually be employed in war fighting, and the attitude of the NATO countries toward the new development." Once again, attitudes are more important obstacles to new technology than is application technique.
14. This refers specifically to Army priorities. Technology, including the use of existing missiles as a vehicle for precision delivery of sub-munitions, can vastly alter the cost-effective qualities of otherwise impractical systems. There remains the question of how best to focus technological initiatives within the Army's very limited resources. What counts is the entire "precision loop" (as defined in this paper) relative to target range priorities.
15. See comments of the Chairman, JCS, before the Senate Armed Services Committee, op. cit. For an excellent summary of Army missiles and their developmental history see "Army Missiles, A New Generation," by E. C. Ludvigsen, *Army*, June 1973.
16. *Hearings Before the Committee on Armed Services*, Statement of the Chairman, JCS, op. cit., p. 54.
17. General H. H. Howze reviews airmobility and the Howze Board efforts in "Winding Up a Great Show," *Army*, April 1974.
18. While this paper does not address Soviet airmobile capabilities, the Chairman of the JCS recently reported to the Senate Armed Services Committee (op. cit., p. 55) that "There are dramatic improvements in the Soviet helicopter forces."
19. See the *Logistics Review*, a seven-volume, extremely comprehensive report published by Hq U.S. Army Vietnam, in 1971. Volume I is an unclassified summary. The report furnishes startling data on the monumental logistics effort throughout the Vietnam operation, as well as a description of numerous experiences and innovations of great value to future logistics operations and technological developments.

20. J. H. Morse, "New Weapons Technologies: Implications for NATO," *Orbis*, Summer 1975, p. 497. The examples cited in this paper tend to verify his thesis that "Since 1945 Western military leaders have made no major changes in their military concepts, methods of operation, doctrines, tactics, or force postures. They have improved their armed forces primarily by developing better versions of familiar weapon systems." He also states: "The trends in new weapons technology are favorable to small units, swift movement, and rapid communications. The thrust in these directions comes from such technical developments as the following: More destructive energy in smaller packages... The revolution in delivery accuracy... The revolution in delivery speed... Vastly improved mobility and communications... and enhanced ability to destroy quickly whatever can be located."
21. James Digby, "Changing Weapon Priorities, New Risks, New Opportunities," *Astronautics & Aeronautics*, March 1975. Digby discusses in some detail the implications of what he defines as "Precision-Guided Munitions." He points out that with these systems accuracy is no longer a function of range, and that "if a target can be acquired and followed during the required aiming process it can usually be hit. For many targets hitting is equivalent to destroying." Among the implications he suggests are: The value of more, inexpensive combat systems over fewer, more expensive ones, since it will be much less desirable to "concentrate a great deal of military value in one place or one vehicle"; the increased importance of concealment, thus concentration of men and vehicles becomes less practical; that even small units can be very powerful when equipped with PGMs or designators that can call in and guide remote PGMs; the potential requirement for much less ammunition for the same effects.
22. Note that these perceptions, which are only fragments of much broader implications to change in today's tactical principles and doctrine, are in effect an extension of concepts offered by Morse and Digby (Notes 20, 21 above). If the benefits of revolutionary technology can be demonstrated to the satisfaction of the professional soldier, such as a capability to substitute precision for casualties, then he is much more likely to adopt and strongly support the necessary analytical and developmental programs.

THE CAPITAL-INTENSIVE MILITARY PRODUCTION
PROCESS AND PERVERSE INCENTIVES*

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SOME COMPARISONS OF RECENT U.S. EXPERIENCES

From 1965 through 1970, the United States engaged in a land war equal to roughly 46 division years. A "division-year" is the commitment, in the theater, of a "division force" (Army or Marine) for a period of one year. Roughly speaking, a division force possesses an authorized strength of about 6500 combat infantrymen, 200 combat vehicles (helicopter gunships and tracked combat vehicles), and between 60 to 100 artillery pieces.¹ Behind these fighting elements are additional men and equipment that bring the total manpower in a division force to around 43,000, to include logistic support troops.²

The 46 division years expended in Indochina compares with 36 division years of U.S. effort in the Northwest European Campaign which commenced on June 6, 1944, at Normandy (see Table 1). Thus Indochina was a sizable land war. However, commitment of combat units to operations provides only a gross criterion upon which to make comparisons between wars and through time.

One criterion is intensity of casualties taken. During the 1965-1970 period, U.S. land forces experienced 235,000 casualties (see Appendix B for derivation of this estimate). By the casualty criterion, the Northwest European campaign was double the magnitude of Indochina. Since theater division force size per division was roughly the same in both wars, the Northwest European campaign was more than 2.5 times as intensive in terms of losses incurred for the men involved. If a figure of 43,000 per division force is employed as representative for Northwest Europe and Indochina, the losses per year per 1000 men were 302 and 118, respectively. But these ratios mask the highly uneven incidence of casualty distribution between different military specialties. For example, about 80 percent of World War II U.S. Army casualties were taken by infantry, yet infantry constituted less than one-fourth

* The views expressed in this paper are the author's own, and are not necessarily shared by Rand or its research sponsors.

Table 1

LAND FORCE CASUALTY EXPERIENCE, U.S. WORLD WAR II EUROPEAN
CAMPAIGNS AND INDOCHINA, PER DIVISION-YEAR OF ENGAGEMENT

Theater	Killed and Wounded	Division Years	Casualties/ Division Year
World War II, European Campaigns			
Northwest Europe	462,470	35.5	13,027
Italy	125,277	11.2	11,185
Sicily	6,675	1.1	6,065
Total	594,422	47.8	12,701
Korean War (Army only)	97,141	19.5	4,982
Indochina (1965-1970)	235,365	46.32	5,083

SOURCE: For the derivation of the "Division-Year" estimates, see Appendix A; for the source of European Campaign and Korean War casualties, also see Appendix A. Indochina War casualties shown in this table are about 27 percent lower than the figures released and publicized during the war. Appendix B presents the reasons and rationale for the adjustment that was undertaken to make the casualty experiences between wars roughly comparable.

of authorized troop strength. A similar pattern was evident in Korea. At this time, the Indochina casualty data have not been analyzed so as to provide a basis to determine incidence of casualties between various echelons and combat specialties. However, it would be surprising if the Indochina War revealed substantial departures from the well-established pattern of relative casualty incidence of past land wars.

The data of Table 1 indicate some of the intractable aspects of war, foreign policy, and military management. However, it is the prospect of physical injury to people and things by which war and military operations influence decisions, and are thereby an "instrument" of foreign policy. Yet the expenditure of materiel and manpower is an aspect of war itself. The expenditure of manpower is what casualties measure. This latter element endows military affairs with certain peculiar qualities which come to a head in the fields of "manpower procurement and management." One attempted way to cope with the problems imposed by manpower casualties is to try to develop equipment and weapons, and to employ artillery and air power to deliver civilian-produced materiel, to substitute for numbers

of fighting manpower, and thereby try to reduce casualties. But modern sophisticated weapons have created some "manpower problems" of their own. At a minimum, weapon development and design appear to be critically interrelated with manpower management.

Another point suggested by Table 1, and the Indochina War casualties in particular, is that U.S. attempts to find ways to substitute capital and materiel for manpower may have been less than was hoped for.³ The Indochina War casualty experience, perhaps more than anything else, brought about a basic change in military manpower procurement, by way of eliminating peacetime conscription. Yet the future of the "all volunteer" armed service is murky and the periodic difficulty in meeting monthly enlistment quotas for the Army and Marine Corps, the services which bear the heaviest incidence of wartime casualties, is cited to support the idea that an "all volunteer" system may have been a mistake. This sentiment, in turn, lends additional force to the quest to find ways to substitute capital for labor. But if we have not done as well as might be possible thus far, ways to improve the weapons acquisition process might therefore be even more critically related to manpower policy. It would be unfortunate to reinstitute the old manpower procurement system before thinking through or understanding some of these interrelationships.

Whatever may be the future of the "all-volunteer" armed force concept, the higher budgetary costs of military manpower have been cited to support high levels of Research and Development spending. The argument is that only by technological superiority can we offset the larger numbers that our opponents possess. Precisely what is meant by technological superiority in this context, however, is not clear. Two consequences, however, can be more costly weapons and a more capital-intensive force structure. That is, the advances in technology are "embodied" in new weapons, or more capital-intensive force elements, or both. Although there is not necessarily a strict relationship between technical improvement and capital intensity, they tend to be related.

These twin ideas in military affairs are often justified by the belief (or assertion) that capital and technology can be substituted for manpower in war. The degree to which such substitution, in fact, is achievable, however, contains many unknowns. It is partly a matter

of technology or knowledge about nature. It is also a matter of how good the weapons are, which depends not only on technology but also on how well the weapons are designed.⁴ Finally, it is a matter of how good the men are, how well they are trained and led, and how they are motivated. Entailed in these three elements--technology, weapons design, and manpower quality--is the entire gamut of military management. Just how well has the United States done on this score?

An important related question is: What is the potential to substitute capital and technology for labor in war? Nor is the answer to this question simple, although it is susceptible to empirical methods. Although the data in Table 1 do not answer these questions, they afford a basis to ponder the following:

- o The ability to substitute capital for fighting manpower is obviously subject to limitations.
- o Despite billions spent on military technology by the United States since World War II, things may not, in fact, have changed much with respect to conventional war. Although an argument might be made that our Indochina casualties were less than half those experienced in Europe, even though the wars were of equal size in terms of "division years," one war was won and the other was lost.
- o American policymakers and the citizenry, around 1965, did not anticipate the casualties we were to experience in Indochina. Rather, an expectation prevailed they would be low and the war of short duration. A case can be made that these expectations were created by the belief that our "technologically superior" and capital intensive forces would enable us to avoid taking heavy casualties.

These and possibly other points suggest that prior expectations derived from an implicit faith in advanced technology and associated capital intensity may have been excessive. If so, then some serious examination of the relationship between technological change and the military production process may be called for.

THE MILITARY PRODUCTION FUNCTION: IS WAR A LABOR- OR CAPITAL-INTENSIVE ACTIVITY?

Labor Versus Capital-Intensive Models of War

The Production Function. A key idea we shall employ is the concept of the production function which takes the general form of

$$P = f(L, K) \quad (1)$$

where "P" denotes some desired product or output and "L" and "K" denote the input of scarce services of productive factors, specifically labor and capital goods, respectively. Capital goods can be specified in terms of particular types of machines and/or inventories appropriate to the production process, as can labor in terms of specialized occupations--e.g., clerks, laborers, electrical engineers, and so on. The essence of "technology" from an economic viewpoint describes (a) the numerical coefficients that specify the amounts of the different kinds of L's and K's necessary to produce a unit of a particular output, and (b), especially, the ability to make substitutions as between the different inputs, or factor services, to produce a given amount of output. Inputs, that is, the L's and K's, can be specified in as fine-grained a way as is necessary to deal with a particular problem. The activity of "production" is that of transforming the services of productive agents (or "factors") into desired outputs. The business of resource management is that of combining or using the diverse productive factors in such a way, either by selecting and combining production processes or by making substitutions as between different factors, so as to produce a given output at the least cost.

It is characteristic of most production processes that the production functions that describe them are "idiosyncratic" in that at given relative resource prices they employ combinations of factors peculiar to themselves. Hence it is possible to describe a product or production process as "labor-intensive," or "capital-intensive," or even "land-intensive." But in different degrees, it is possible to make substitutions as between factors in the production of most outputs. That is, the ease of substitution as between capital goods and labor (as measured by the concept of the "elasticity of substitution") may be

limited in some activities (e.g., live entertainment) and relatively easy in other activities (e.g., weaving cloth). For this particular reason, all production processes cannot be unambiguously classified as labor-intensive or capital-intensive, unless one also specifies the price ratios of the relevant factors. But under certain conditions, it is possible to describe some processes in terms of factor-intensity.

Military activities may also be described as "labor-" or "capital-" intensive. Such models are implicit in two prominent streams of military literature, which will be labeled here the "Continental" and "Maritime" models.

Labor-Intensive Land Forces and Manpower Exchange. Writing in 1830-1832, Karl von Clausewitz, although ignorant about the concept of a production function, provided the following description of one as it pertained to land war, as well as some of the important, then-prevailing cost factors.⁵ Infantry was the most important and most independent of the three combat arms, artillery was entirely dependent upon infantry to protect it, and cavalry could most easily be dispensed with. However, a combination of the three arms gave the most strength.⁶ In modern jargon, these three inputs are "complementary."

According to him, a Prussian 800-man infantry battalion, a 150-horse cavalry squadron, and an 8-gun battery of 6-pounders "cost nearly the same, with respect to both the initial expense of equipment and its maintenance."⁷ Thus infantry was the most labor-intensive combat specialty, artillery the most capital-intensive, and cavalry was intermediate between the first two. If one intended or was obliged to fight in open country, where the battle can be decisive, then the army should have ample cavalry to screen one's maneuvering and to have the ability to turn any enemy tactical withdrawal into a rout. An emphasis on defense and passive warfare dictated a greater amount of artillery, which, being costly, might also be employed more intensively by wealthy countries. But if the state were strong in the sense that the population identified with it, a militia and an ample national levy (i.e., conscription) could permit a force to be intensive in infantry, so that the ratio of one 8-gun field artillery battery to one battalion of infantry might fall to one battery per two or three battalions.⁸

Thus, Clausewitz--in terms of the concepts of modern production theory--recognized substitution possibilities. He emphasized that lack of "the two subordinate arms" (cavalry and artillery) can "be compensated for, provided we are so much stronger in infantry, and the better the infantry, the more easily this may be done."⁹

On the other hand, there were limits on the amount of artillery one could have relative to infantry because it required infantry to protect it. Moreover, it necessitated a larger logistics apparatus and thereby encumbered mobility. It should also be pointed out that the cavalry ratio entailed some delicate balances. A larger number of horses necessitated that an army keep moving for reasons of feeding the animals, or that fighting be confined to areas (and in seasons) that provided lush forage. (However, as the French illustrated when they ate their horses in the 1812 retreat from Moscow, the cavalry and artillery arms provided certain logistics advantages.) But overall, in terms of modern production theory, Clausewitz asserted that land forces (and land war) were "labor-intensive" in the sense that labor (infantry) was clearly a limitational factor. It could be almost completely substituted for artillery and cavalry. Although artillery and cavalry could be substituted for infantry, a minimum amount of infantry was necessary to protect artillery, to a degree determined by terrain and the natural obstacles it might afford. Cavalry could be entirely dispensed with in mountain country, and it could be a nuisance in heavily wooded country.¹⁰ Thus terrain was a critical complementary factor affecting cavalry and artillery intensity.

To capture this point, Eq. (1) above could be rewritten as

$$P = f(L, K^*) \quad (2)$$

with

$$K^* = g(K, N) \quad (2.1)$$

whereby N denotes "land," and, in particular, specific military qualities of the terrain. In this construction, it is implicit that the principal usage of capital occurs through increasing the ratio of the more capital-intensive cavalry and artillery arms. The amount of capital that could be put into foot infantry was (and still is) limited by a soldier's

weight-carrying ability. Equation (2.1) emphasizes that the degree to which capital can be substituted for labor (infantry), by means of cavalry and artillery, is sensitive to terrain and geography. It also incorporates the point that if one does not have adequate military terrain, it can be substituted for by investing capital in fortifications, prepositioned stocks, and so on.

Clausewitz also emphasized another important point which might be incorporated into the general concept of a production function as it applies to land war. When military forces are regarded from the viewpoint of use in war, as contrasted with their peacetime existence, the focus turns to the subject of "The Engagement." An arresting statement is: "Now it is known from experience that the losses in physical forces in the course of an engagement seldom show a great difference between the victor and vanquished, often none at all...." The decisive loss for the vanquished takes the form of prisoners and abandoned materiel, which is facilitated by cavalry cutting up retreating battalions. The important count is prisoners and captured guns.¹¹ It is important because prisoners are a proxy for shattered morale of enemy troops, and a corrosion of their will to fight. Nevertheless, land war necessitates its minimum ante.¹² These are the casualties of the engagement, or of what today is the complex of small unit fire fights that constitute a major engagement. It was necessary to incur casualties in order to inflict them on an enemy who, in turn, feels constrained to withdraw, either to yield ground or to lose prisoners and materiel should the withdrawal get out of control.

The ground, if contested, is either worthwhile for its own sake, or it might possess military value that could enhance effectiveness of subsequent operations. Both casualties inflicted in an engagement and the prisoners taken as a result of a successful engagement were intermediate outputs that contributed to attaining the ultimate goal of eliminating or greatly reducing the opponent's ability to conduct military operations. In this event, then, either his territory can be taken at low cost, or new contractual relationships affecting trade, alliances, and so on, can be established. In achieving these broader aims, one's own casualties incurred in the engagement(s) were an input. Since land forces were

(and are) relatively labor-intensive, their employment in war entailed a somewhat peculiar usage of labor or manpower. In normal production processes, it is the services of the production agent, labor, that is used. Deaths and injuries which occur, and which differ as between activities (e.g., coal mining versus school teaching), are accidental happenings. In warfare, however, as Clausewitz's remark suggests, elements of the manpower must be more or less purposefully expended. A recognition of this point raises the question of how the production function of Eqs. (1) and (2) might be specified so as to take account of this peculiar aspect of military resource management. But before trying to tackle this problem, let us turn to the capital-intensive model.

The Capital-Intensive Maritime Model. In contrast to the Continental labor-intensive model described above, England--by around the turn of the 18th century--evolved what may be described as a "capital-intensive" approach to the subject of war and foreign affairs. Insularity, the technical advent of the deep water, long-hulled ship,¹³ and the growing revenues and gross national product obtainable from commerce (and later manufacturing sustained by foreign trade) combined in mutually complementary ways to foster the capital-intensive approach to war and foreign policy.

Prospering commerce and manufacturing permitted England to enjoy a favorable trade balance whereby the resulting gold holdings could be used, through diplomatic means, to acquire allies or auxiliary armies that would absorb a disproportionate share of the killing in war. The Royal Navy, a capital-intensive military instrument as compared to labor-intensive land forces, nicely complemented these diplomatic techniques. The Navy, along with small British land forces, could be employed to seize strategic pieces of real estate like Havana and Louisbourg that could be useful pawns in post-war negotiations. These military operations, however, were adjuncts to major continental land wars, like the War of Spanish Succession and the Seven Years War, in which the heavy casualty production and absorption were experienced by others. The rationalization of this model harnessed Alfred Thayer Mahan's intellectual talent which, in turn, found a congenial reception in American military force planning

and foreign policymaking around the turn of the century. Mahan asserted that the payoff from seapower was to secure a "disproportionate share" of the benefits from seaborne commerce and colonial holdings.¹⁴ Although there appears to be no evidence that Mahan studied Karl Marx, the affinity of his thinking to Marxian doctrine is striking, and has not gone unnoticed.¹⁵

The techniques and instruments which could permit the British to characterize land war as "our old style of expedition--a landing, a short march, and a good fight, and then a lounge home again,"¹⁶ broke down during 1914-1918. The British professed to be shocked by this experience with large infantry casualties. However, the case can be made that what was new to the British was "old stuff" to Germans, Austrians, French, Russians, and Turks, who had been engaging in large-scale casualty exchanges for centuries.¹⁷ Even Americans, within the short span of the Republic's history, acquired from the Civil War an insight that had more in common with continental culture than what was available from the English heritage that dominated most aspects of American outlook.¹⁸

It must nevertheless be acknowledged that this maritime, capital-intensive approach to military policy worked quite well for England from the 16th up to the 20th century. For whatever it was worth, it acquired an empire as a by-product of helping maintain a balance of power on the continent. Its support of allies plus the hiring of mercenaries (and Sepoys in India) enabled it to influence the course of major land wars to a degree greatly out of proportion to the British forces that were engaged. Naval engagements did not entail the large manpower losses that characterized land battles and campaigns; and British land forces, when used, were employed on a modest scale.¹⁹

Blending the Models and Expanding the Production Function. The use of capital-intensive military instruments--particularly naval and later air forces--could enable a country to avoid large-scale manpower exchanges, although the intensity of casualties for engaged combatants can be more severe than it is for combat infantry. However, the exchange of materiel--specifically the "weapons" themselves--can be a critical part of these operations. In air war, when it acquires the quality of attrition as between opposing air forces, combat crew attrition, and, especially,

ability to train highly skilled personnel to replace combat crew losses, can be a decisive factor affecting the outcome. Since such training is costly, aggregate materiel resources--in the form of capital invested in the weapons and the specialized combat manpower--of the opponents may be ultimately decisive in air and naval war.

Once a single side's naval or air force dominance is established, these forces may be used in either or some combination of two ways. First, they may be used in the land war. This usage may be regarded as an attempt to substitute capital for labor in the land fighting, mainly in the form of ship-borne or airborne fire support. Second, they may be employed to try to destroy the enemy's physical assets. This latter usage might be called the "real estate busting" approach. It appears to have been deeply embedded in British tradition. The burning of Washington, D.C. in 1814 provides an example.

The English and French, prior to the 16th century, both focused on real estate destruction by conducting operations which one historian of the British Navy termed "cross ravaging," whereby port towns were attacked and usually sacked. The sacking phase of the operation had the incidental but very important by-product of motivating the troops. In fact, it may have been a necessary aspect of operations given the point that fiscal-taxing systems were very primitive and unreliable in those days, and alternative ways to finance military operations had to be employed. Cross ravaging died down, however, after the advent of the rich maritime trade to the new world. Seamen like Hawkins and Drake had more lucrative opportunities than did their predecessors, a condition which no doubt also served to enhance land values in Channel-coast towns. However, there was a distant but firm historical precedent that could incline the British to warfare that focused explicitly on property damage.

The predilection to destroy real property could derive a strengthened rationale from the belief that industrial capacity contributes to military capability. From the British viewpoint, this connection was established since the 18th century; however, during the early period, Britain was served in this manner by means of the gold holdings and foreign credits which its industrial capability generated, and these financial resources permitted the hiring or support of others to fight. But as

other countries became industrialized, Britain's comparative advantage declined. Industrial capacity, along with the transformation of agriculture, then permitted countries to raise and equip relatively larger armed forces. Artillery ratios simultaneously increased. The adoption (or development) of the "long recoil" principle in artillery--of which the French '75 of 1896 was the forerunner--revolutionized artillery tactics and usage.²⁰ The long recoil, by virtually eliminating displacement of a piece²¹ upon firing (and therefore the need to relay after firing), permitted firing rolling and box barrages over the heads of friendly and advancing infantry. All these meant a manyfold increase in ammunition consumption, which the industrial capacity was strained but able to provide. The *materiel schlacht* of World War I was a natural consequence of these developments. And so it seemed that constraining an opponent's industrial capacity might assist a war effort. Naval blockades and submarine warfare of World Wars I and II, and strategic bombing of World War II, were a consequence. But these specialized military efforts, themselves, required increasingly capital-intensive military means. How much their extensive and tactically successful employment by the British and Americans in the two wars against Germany really affected the outcomes of those wars, however, remains ambiguous. It is ambiguous because a case can be made that Germany's defeat in both wars can be attributed to the fact that it simply ran out of military manpower in the young age groups. And these were mainly chewed up by allied infantry who, in the aggregate, experienced somewhat higher casualties than did the Germans.

Nevertheless, it should be acknowledged that industrial capacity plays a role in war. Accordingly, the production function of Eq. (2) might be expanded as

$$P = f(L, K^*, I^*) \quad (3.0)$$

$$K^* = f(K_w, N) \quad (3.1)$$

$$I^* = f(L, K) \quad (3.2)$$

where I^* in Eq. (3.0) denotes industrial capacity. The specification of I^* in Eq. (3.2) asserts that it is a function of civilian-sector L , and K , to encompass the point that the production of munitions, replacement

equipment and spare parts, and so on, may be either capital- or labor-intensive, depending on resource management in the civilian economy or in government arsenals, ammunition loading plants, and so on.

The rise of industrialization and its associated capital accumulation have made most production processes more capital-intensive, and much evidence (both cross-section and time trend) can be marshaled to support the assertion that most countries' armed forces reflect the degree of capital intensity of the national economies that support them. Whatever impact industrialization and higher capital intensity have had on the military production function, they have at least three apparent and perhaps mixed effects. First, as illustrated by World War I and perhaps World War II, they facilitated allocating a much larger portion of a nation's manpower to fighting. The innovations in artillery tactics (permitted by a rather modest improvement in gun design) led to a manyfold increase in ammunition expenditure, which would not have been possible if there had not also been railroad (and later) motor trucks to move the tonnage. Finally, industrial capacity (combined with the internal combustion engine) permitted mechanization of land forces and intensive use of aircraft. The tank supplanted the horse, artillery densities increased, and the capital invested per fighting man increased greatly.²²

Simultaneously, manpower requirements to maintain the equipment and operate the logistic apparatus so as to feed the tubes (and the bomb racks) also greatly increased. The ratio in armed forces of noncombatants to fighters (the counterparts of 19th century infantry, horsemen, and gunners) is now somewhere in the neighborhood of 3 or 4 to 1.²³ If one folds in combat air crewmen and air base personnel, the ratio of non-fighters to fighters increases sharply as a function of the number of air wings per division. Although there is ambiguity as to the overall effect of the increased capital intensity of certain armed forces, it has created a requirement for a substantial military support apparatus, which itself is composed of both people and capital equipment. Accordingly, the production function concept might be specified as follows:

$$P = f(L_c, K_w^*, I^*, S^*) \quad (4)$$

$$K^* = f(K_w, N) \quad (4.1)$$

$$I^* = f(L, K) \quad (4.2)$$

$$S^* = f(L_s, K_s) \quad (4.3)$$

S^* denotes a military support apparatus composed of support personnel, L_s , and the equipment they use, K_s , to maintain the weapons, move the materiel, provide the personnel services, and so on. These personnel should be differentiated from L_c , "combat labor," like riflemen, gunners, tankers, and air crews and the crewmen on combat ships from support or service personnel, L_s .²⁴ K_w and K_s separate capital invested in weapons and combat vehicles from that required for support equipment, which ranges from checkout gear through trucks for the logistics apparatus to computers required to handle inventory and other data processing. I^* is retained to take into account the role of industrial output, including munitions. The expression K_w is to emphasize that usage of important capital-intensive military elements like artillery, armor, and air is sensitive to terrain, or "land" (N).

The production function of Eq. (4) seeks to capture the following arguments. First, a sharp distinction should be made between L_c , combat labor, and L_s , or military personnel who perform support functions. Although the distinction, especially in armies, is not airtight, a strong case can be made that they are fundamentally very different "factors" of production. For example, physical standards need not be as exacting for L_s as for L_c , and an uncritical extension of L_c standards to L_s may reduce the potential supply (and hence increase the supply price) of manpower available to perform the L_s functions. Moreover, there may be a very high real but hidden opportunity cost resulting from this practice. Given the very large relative proportion that L_s is of total military manpower, the preclusion of some people from these specialties can cause many who would be prime combat personnel not to be available for that role.²⁵ Finally, because L_c experiences the majority of casualties, there are special incentives and other uniquely military management problems associated with this subset.

Second, K_w is the primary focus of present day weapon engineering development. The subject of substitutability between it and other elements of Eq. 4, especially L_c , is central to many problems of military management. The composition and qualities of K_w in large part drive the magnitude of I^* and S^* . The more sophisticated the weapons, the larger S^* and I^* tend to be. The more munitions K_w can expend, the larger is I^* , which, in turn, requires a larger S^* to move the tonnages. As S^* grows, it buttresses its further expansion because more drivers and repair people need more cooks, doctors, and drivers, who also need cooks and drivers.

Third, S^* has another important facet which can be illustrated the following way. Consider two equally-sized and equally-costed military forces, like a field army or a theater air force, which we denote by subscripts "b" and "r" for "Blue" and "Red." Let each force's combat elements be denoted as "C." Hence,

$$\begin{aligned} S_b^* &> S_r^* \\ C_b &< C_r \end{aligned}$$

Both forces could have equal fighting capability, where fighting capability is measured as an integral of time. The $F = f(t)$ curves can further be specified as sine curves since all forces appear to exhibit surge capacity and behavior. Although $F_b = F_r$, F_b will possess a higher "steady state" capability; whereas F_r will be capable of higher combat (or operational surges) but will experience lower troughs. The reason is that because F_r has a relatively small S^* , it is incapable of sustaining intense operations for its otherwise formidable high ratio of combat elements. (Perhaps Red does not care about this if he is confident, for example, that he can reach the Rhine or the English Channel before he starts descending to his trough.) But whatever the basis for the choice, it is or should be a matter of strategic policy. And for this reason, the S^* portion of the production function should not be criticized or evaluated in ignorance of the worth (or demerits) of "steady state" versus "surge" fighting capability.

Fourth, the tradeoffs as between I^* and S^* , and as between L_s and K_s within S^* , are perhaps an area where the conceptual and analytical

problems may be fairly straightforward, and where conventional analytical models (including the neoclassical production function) might have their maximum fruitful application, if not be devoid of creating mischief. But the tradeoffs as between L_c and K^* are a different matter. This subject entails the fields of applied tactics, weapons design, and military operational research. By military operational research we mean what emerged from World War II, which was the purposeful endeavor to identify and understand military production functions at the level of the tank turret and cockpit, not the applied mathematics, model-building, and computer simulations that characterize and dominate the subject today. This is not to assert that the economic concept of a production function has no relevance to war and force planning. Rather it is to suggest that a fair amount of disaggregation is called for before it can be reconstituted so as to be useful with regard to the fighting side of the business.

The "Exchange Aspects" of War, the Question of Substitution, and the Casualties

A Suggested Model of War. The previous section described Clausewitz's land forces "production function," and iterated his assertion that the land forces production function was labor-intensive and, specifically, it was infantry-intensive. But his focus on the "engagement" emphasized that war was a "labor-intensive" activity in a peculiar way in that casualties constituted a literal spending of people. The engagement also entailed an exchange which, according to Clausewitz, was roughly equal. Clausewitz no doubt based much of his theory on his own first-hand experience in the Napoleonic wars, for which a fair amount of evidence can be marshaled to support the hypothesis. However, a more appropriate rendering of his "model" might be as follows: Given opponents of relatively similar sophistication and force size, and if it were a meeting engagement (as many battles in the Napoleonic wars were), *a priori* it would be unwise to try to predict what the casualty exchange rate would be. Indeed, a sensible military man would be wise to plan on their being equal. If one had luck in reconnaissance, or by hard marching could catch the opponent's army strung out along the roads or before his force

could be drawn up in battle order (as did Napoleon against the Prussians at Jena-Auerstadt), then a favorable exchange rate could result. But it was the disorganized and uncoordinated withdrawal that could lead to really serious loss (and so was the Prussian Army destroyed at Jena).

It was further implicit in Clausewitz's thinking that a *favorable* force ratio should be sought. His reasoning was no doubt more subtle than a simple interpretation of Lanchester's Law. In addition to providing more guns, a larger force provides more wherewithal to maneuver and, especially, resources for a reserve which is a necessity if a commander is to retain options during the engagement. Finally, a larger force means that one can absorb more casualties before feeling constrained to break off the engagement, which entails the delicate risk of losing more troops in the withdrawal (including desertions).

Given the view that the casualty exchange will be roughly equal, which in the 19th century may have been valid because all parties had roughly similar force structures and employed roughly the same kinds of weapons (or which might be the way a prudent military planner might or ought to think, given unclear evidence to the contrary), there would be no need to incorporate in a model of war any allowance for differential combat effectiveness. As Wellington put it with respect to his campaigns in India, "If I had rice and bullocks, I had men, and if I had men I knew I could beat the enemy." (Notice Wellington had both a manpower supply price and a production function model in one sentence; however, he always was a rather terse fellow.) But in modern times we entertain the idea that one side can gain a consistent edge in fighting productivity. Correspondingly, models of war should be appropriately refined to accommodate the hypothesis.

In undertaking this task, it is also possible to address a nagging question of just how the production function models of Eqs. 1-4 might be related to war. The specific question is: What is "P"--i.e., product or output; more to the point, what are relevant measures of P? A list can be offered, and debates on the point can be extensive. Heading the list might be the abstraction, "National Security," and next could be the somewhat elusive "Victory." Or it could be ground taken or held. But here it is argued that ability to inflict casualties on enemy forces

in war, and particularly in engagements, should be the relevant measure of the product or the productivity treated in Eqs. 1-4. In land warfare, our casualty criterion would measure troop losses and tank kills; in air war it is aircraft shot down; in naval war, it is combat ships and aircraft lost. It seems sufficient to recognize that the ability to inflict casualties on an opponent is a necessary condition to conduct war successfully. But one generally has to incur casualties to do this. The immediate objective of the force planner, weapon designer, and the field commander can thus be narrowed to strive to attain favorable casualty or damage exchange rates. In a battle, or war, relative casualty exchange effectiveness then impacts upon morale in such a way as to yield prisoners, or to reduce the opponent's effectiveness, often in subtle ways--e.g., inducing aircraft to release bombs from higher altitudes or at shallower dive angles. Thus captured prisoners (and sloppy bombing tactics) are a payoff from the straightforward killing business. The larger the prisoner count, the more favorable subsequent force ratios will be; or the quicker the opponent runs after shooting, the more territory one acquires. Of course, these cumulative advantages can be offset by shoving more resources into the process. But then increasing cost is incurred to attain military objectives, which eventually impacts on the taxpayers.

It could be asserted that prisoner count and sloppy bombing or other operational tactics are really the relevant measure of one's effectiveness. We would not disagree. However, these measures not only say something about the effectiveness of one's forces, but also they can speak most loudly about the overall morale and fiber of the enemy's troops and crews. His morale, of course, is a function of our effectiveness. But it is also an important function of other things beyond our control.

For this reason, we suggest that casualty and damage production in the engagements are a more appropriate measure of effectiveness. This measure also has the merit of being estimated in peacetime exercises, and simulated field trials, in the form of hits and near misses relative to target systems that are designed to appear and behave like the real thing.

In advancing the idea that casualty production in the engagement is the preferred productivity (or effectiveness combat measure), it should nevertheless be recognized that casualty exchange rates in actual war and engagements can often reflect the consequences of an edge with respect to troop or crew motivation, and morale. For example, to the extent that Red's troops cower in their foxholes, or do not stick to their guns, or do not expose themselves so that they can see what they are shooting at, then they will inflict fewer casualties on Blue. Hence one side, like the Israelis, can reveal an impressive engagement exchange rate relative to Egyptians. The essential difference, of course, is like that of a fight between two men in which only one is a fighter. All this says, of course, is that casualty production in the engagement is an imperfect measure.

This concept of product also encompasses, or is consistent with, what most planners and analysts appear to mean by "effectiveness." That is, the effectiveness of a weapon (and its associated organizational or force structure element) contributes to the "productivity" of the force; or our "P" is actually the consequence of an aggregation of the effectiveness of the weapons and tactical units composing the larger aggregation of organized units.

The focus on the casualty exchange aspects of war argues that one also confronts the "productivity" of an opponent's forces. To employ one's weapons and troops necessarily requires that they must expose themselves to enemy fire. He also has a strong incentive to try to destroy unfriendly forces, or to disrupt their operation. One must therefore be prepared to take or "absorb" casualties or losses.

Recognition of the casualty production and absorption aspects of war suggests the following "model" of the subject.

$$O_E = f \left(\frac{P_b}{P_r}, \frac{A_b}{A_r}, \frac{F_b}{F_r} \right) \quad (5)$$

Here the focus is on ratios with respect to opponents; Blue and Red are denoted by the subscripts b and r. The capital letters represent the variables:

- P, productivity in inflicting casualties;
- A, willingness to absorb or accept casualties;
- F, force size specified in terms of combat or fighting elements like infantry, armored, or artillery battalions; or air wings; or combat ships.

O_E represents the outcome of an engagement, in terms of probability of winning or losing. The model can also be extended to the outcome of a war, O_W .

"Productivity," as argued above, is the ability to inflict casualties on an opponent. Although formally it can be specified in the form of Eq. (4), it can also be regarded as a function of three subtle elements: (a) combat skills, including ability to lead and handle small units, the qualities which are the product of training, indoctrination, and other ingredients like the basic skills of mountaineers and farm boys that contribute to being good field soldiers; (b) the relative effectiveness of materiel items (equipment and munitions) that comprise the "tools of the trade"; and (c) generalship and high level management skills, which include the selection (and removal) of generals. Thus President Lincoln, by employing the expedient of firing losers until he found winners, merits recognition as a first-rate military manager. Emperor Franz Joseph, on the other hand, revealed an opposite tendency when he failed to designate a royal prince (who was perhaps the most able field general) to command the Empire's forces confronting the Prussians in the 1866-1867 war because he apparently feared that a possible defeat would unduly damage the prestige of the Royal Household. It is implicit in Clausewitz's view that the productivities as between opponents would not differ greatly, if at all. However, this is an empirical question.

The ability to absorb casualties in absolute terms is partly a function of the force ratios and, ultimately, available military manpower. That is, the side with a larger population (or force) should defeat the smaller side (or force), provided both sides have equal military skills and an equal stomach to absorb each other's casualty production capability. The outcome of the American Civil War seems explainable in these terms.

However, one should separate out the force ratio and military manpower variable, and focus on the capacity to absorb casualties per se.

Casualty absorption ability within the context of the military sector, thus defined, encompasses such abstract qualities as morale, valor, and discipline. This capacity is produced by a variety of techniques and associated incentive systems. Somehow, to the admiring dismay of contemporary observers, the Ottoman Turks imbued the Household Troops with the notion that it was better to die on a campaign in a foreign land than to die in bed at home. By the middle of the 16th century, bands of Swiss pikemen in pursuit of profits stiffened their mutual resolve and incentive by promptly killing the colleague who wavered. It was the resulting solid line of pikes that deposed the armored knight in Western Europe, not gunpowder as some technological interpretations of history would have us believe. The battle of Waterloo (or any of Wellington's victories) was not "won on the playing fields of Eton," but rather, it was won in the gutters of Glasgow and London that produced the infantry which possessed at least one British virtue: "steadiness." (Wellington also described that "article" as "the scum of the earth.") Finally, belief in a cause, a leader, or one's organization can affect the ability to absorb casualties. As time went on, Napoleon extracted the cream of the French Infantry to form his Guards Regiments, of which there was an Old, Middle, and Young Guard. Despite fearsome casualties, they failed to turn the trick in the final attack at Waterloo; nevertheless, they managed to sulk off the field *in formation* and thereby displayed to the amazed British a point on how to play the game.

If war entails casualty exchange, in which casualty absorption capability is a critical variable, then force ratios might best be specified in terms of those elements of the force structure which are most likely to bear the incidence of casualties. Specifically, it should only include combat troops and crews, or the L_c in Eq. (4).

For other purposes, such as the analysis of air battles, major weapons like aircraft, or tanks, and hence K_w of Eq. (4), can be specified. For much if not most serious analysis, it is necessary to disaggregate F. For land forces, it should be at least disaggregated to the three major

combat arms: infantry, armor, and artillery; and, often, further disaggregation is called for as between, say, towed and self-propelled artillery, mechanized and foot infantry.

One reason for specifying F in Eq. (5) is because of a long-standing concern with "numbers," or relative force size, in battle, campaign and force planning; or "force ratios." This concern is also evidenced in analytical literature centering around F. W. Lanchester's model, which is simply the F elements in Eq. (5). Lanchester further specified that engagement damage or casualty exchange rates were a function of the squares of the opponent's forces, for which he and other students used the notation " n "; hence, the famous n -square law of combat.

Attempts to verify Lanchester's hypothesis, including an alternative linear law, have not been entirely successful, or at best mixed (indeed, some students contend there is no evidence to support it).²⁶ One reason, in our view, for this unresolved issue may be the point that inadequate account is taken of the relative productivities between opponents.²⁷ Nor have any empirical studies we have seen separated out ratios as between, say, artillery and infantry. For these reasons, and because force ratios continue to loom important in the minds of field commanders, it is argued that force size and hence ratios not be ignored in analysis of war.

The Production Function and the Casualty Exchange Rate. The formulation of Eq. (5) is intended to assert that, with respect to opponents, if two sides are equal with respect to two of the variables, the side that has the edge in one of them will win. For example, if one side enjoys a productivity advantage of, say, 1.5 to 1, it is able to impose 15,000 casualties while taking 10,000. But if the side experiencing the 15,000 casualties is able and willing to absorb more than 15,000, it will prevail or "win."²⁸ This assertion is merely another way of saying that each military operation has (or should have) an objective, and a commander does not normally attach infinite value to attaining it. (Reducing his force to zero, so that he is incapable of further operations, is another way of interpreting the idea of an "infinite value"). The same assertion can be extended to a war, in which case the "infinite value" implies destruction of the society.

Let us now turn to the Eq. (4) formulation of the production function and try to relate it to Eq. (5). Two key relationships can be developed as between these formulations. First, L_c , or "combat labor" constitutes the troops that are expended, or casualties absorbed, A , in Eq. (5). Second, a number of substitution possibilities in Eq. (4) may be available so as to affect P , or productivity, so as to provide a favorable exchange rate, as expressed in Eq. (5). Among these are:

- o Capital invested in weapons, K_w , as exemplified by higher artillery densities, may permit inflicting more casualties on the enemy.

- o Industrial capacity, I^* , which, among other things, provides and permits munitions expenditure for the same end.

- o Higher sustained rates of fire per gun (or loads or sorties per aircraft) or I^* , may be substituted for number of weapons, K_w , or vice versa.

- o The way weapons are designed, at a cost, to possess greater reliability and ease of maintenance entails substitution possibilities with respect to the support outputs expressed by the function I^* .

- o Industrial capacity, I^* , may be substituted for military support, S^* , by discarding damaged or worn systems and replacing them with new ones. In this fashion, more of a given amount of military manpower could be L_c , which affects the force ratio, $\frac{F_b}{F_r}$, in Eq. (5). Or, another way of looking at these relationships is that a uniformed military person in the field is replaced by capital and labor services in the civilian sector.

The questions of just what are the relevant substitution possibilities, and how they might be affected by technical change and development are very important for resource management. Perhaps the most important single question is that with regard to L_c , or combat labor. With respect to land war, it may be extremely difficult to substitute capital (machines) for labor (infantry) in order to improve the casualty exchange ratio. It requires sophistication on the part of all participants in the military decisionmaking process, as well as sensitivity on the part of high level civilian managers. The source of these difficulties is twofold.

First, the history of military art reveals great capacity to revise tactics in ways to counter new equipment and tactics, to include ways to spoof sensors, to operate under conditions when or where specialized equipment is least effective, to avoid creating lucrative target systems for high and costly firepower systems, to simulate targets that induce such systems to expend ordnance, to copy quickly weapons that prove highly efficacious, and so on.

Second, as firepower becomes greater, troop (and target) densities become smaller. Greater emphasis is thereby placed on training, doctrine, initiative, and combat skills at the small unit level. Individual motivation (and incentives) then become critical. It is therefore critical to find and develop the "fighters," or the people who possess a comparative advantage as combatants. And with finding them, they must be motivated, because their motivation affects P , or productivity, in Eq. (5). These matters are aspects of manpower supply and its supply price, which entails a critical relationship to the concept of the production function.

THE PRODUCTION FUNCTION AND INCENTIVES

Micro-Incentives

When the concept of a production function such as $P = f(L, K)$ is used in economic analysis, it is assumed that "operators" in the industry are earnings maximizers, or that they are obligated to behave "as if" they were due to an incentive to survive when subject to more severe budget constraints that arise because of either adverse demand or cost shifts. Such behavior requires not only employing the optimum mix of inputs given factor or process substitution possibilities, but also by seeking to economize on the absolute quantity of physical resources used. Thus if the product, P , is Number 1 winter wheat, thousands of Kansas and Oklahoma farmers may be assumed to operate subject to the constraints of a production function slightly more complicated than that of Eq. 1. That same production function simultaneously reflects the efforts of hundreds of suppliers who are competing to provide these operators more efficient farm machinery, and ingredients like fertilizers and pesticides. As improvements occur, the production function shifts in ways satisfying

both to farmers' profits and consumers' budgets. There are also thousands of county agents and researchers at agricultural schools and elsewhere creating and disseminating information about techniques on how to use the improved inputs. The inputs of these supplying industries can be reduced to some appropriate conglomeration of K and L , and if we waive the "minor" aggregation problem, the simple form of Eq. 1 (or even more complicated forms) provides a handy way to treat aspects of the behavior of the winter wheat or any other private sector industry.

Explicit in this construction, of course, is the idea that the production function equation describes the "best" technology, and operators employ such incidental but vital knowledge about the best planting time, when to dust to reduce disease, the niceties of contour plowing, and so on. (These latter are the counterpart of "applied tactics" in military lexicon as contrasted with the more narrowly defined technology that is the province of the engineer.)

With respect to the military production function, the K_w and the L_c elements (Eq. 4) are "outputs" of military management in all its complexities. Development and procurement of the weapons composing K_w are impacted upon by a variety of incentives, some of which are political in the sense that they serve budgetary and roles and missions objectives. Generally speaking, weapons during the past twenty or so years have been designed to achieve high technical performance but with limited insight on just how an increment of technical performance may contribute to combat utility (in many instances, an increment of technical performance may actually detract from combat utility). Moreover, especially with land forces weapons, design does not seem to have been geared to any particular subset of the population that may, in fact, be the best, or extraordinary tank gunners, grenadiers, and so on. Indeed, there appears to have been no systematic attempt to discover just what kinds of individuals may, in fact, reveal high probabilities of becoming the "aces" of a given specialty. If these individuals could be identified, and their skills further enhanced by the "right" (but presently unknown) training programs, it is possible that entirely different weapons concepts could emerge as the object of engineering development. (It is our suspicion that some would be less costly and more austere than present ones, and would, in

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turn, permit a smaller S^* function in the Eq. (4) specification.)

If one takes a "long view" of warfare--of about 100 years or so--a clear consequence of technical change affecting weapons and tactics has been to accentuate the importance of individual and small group motivation in land war. With aircraft, individual motivation in combat was a critical ingredient at the outset. The rapid-fire, high velocity small arm (both permitted by the advent of smokeless powder) necessitated troop dispersal and thereby eliminated the ability to "command and control" large groups of men in actual combat. Hence the squad and even the fire team became quasi-autonomous tactical elements; and the initiative of "leaders" and individual soldiers at these levels became increasingly important in war. Hard upon these changes came the aircraft and tank. With both kinds of weapons, the "team"--either of a gunner and tank commander, a bombardier and pilot, or a single pilot of a dive-bomber, become the key combatants. The tank and airplane were followed by the anti-tank and anti-aircraft weapon, with their crews consisting of one or two key individuals. Each of these weapons or small tactical units necessitates that individuals expose themselves to fire. When employed in larger aggregations, like a platoon, tank-section, or aircraft flight element, a degree of coordination resembling that of professional football is required. In virtually all instances there is both necessity and ample opportunity for key individuals to make judgments and hence decisions regarding the degree to which they exercise maximum skill and effort in performing an assigned mission. Incentives impacting on these individuals thereby acquire a critical role in determining the end-output--or the "quantity" of the service expended, if one wants to be sticky or arbitrary about the concept of a "production function." Equally important is the matter of discovering (or "stumbling upon") the individuals who possess the comparative advantage in wartime operation of these systems. On both the matter of discovering the fighters (i.e., those with the comparative advantage) and motivating them, our performance has been less than systematic.

In the case of land forces--as evidenced by U.S. World War II and subsequent behavior--the very sharp rise of technicalities simultaneously operated to cause a large proportion of the more intelligent and astute

people to be allocated to (and have an opportunity to join) the technical services, including the Air Force, Navy, and the Army's own technical services. These services, incidentally, provided a much lower probability of being a casualty, as well as an overall more pleasant daily wartime working life--what with closer access to supply depots, quasi-permanent living facilities, to say nothing of the gratitude of liberated civilian populations. (Thus there emerged the dichotomy, in troop lexicon, between "fighters" and "lovers.") A consequence of this development was that a disproportionate share of the less-gifted people ended up in combat arms. At least in World War II and perhaps to a greater extent in Korea, many of these troops had a chance to be led by combat-wise officers and, especially, noncommissioned officers. In Indochina, given the officer rotation policy, the average enlisted man in a rifle battalion--with a one-year tour--had more combat experience than did his battalion commander. Thus the combat skills of fighters and their leaders may have had an uneven but downward trend.

With aircraft, a further problem arises when they are used in land war. Accurate bombing requires both target identification and making a careful pass, which necessitates some minimum but uncomfortable exposure to enemy fire. It is easy to reduce this exposure and thereby enhance both probability of survival and of missing the target. A frequent reaction is to do just that. If the designated target is not destroyed, ground troops will still have to take it and incur casualties doing so. If it is a heavily defended deep interdiction target (like a bridge), the same target may be assigned to another unit tomorrow, and still another the day after. Each bombardier (or dive-bomber pilot) understands this procedure. Some missions later, the target might be destroyed. (Recall, all of this horizontal bombing was done in World War II with a Norden bombsight, with which it was highly feasible, with six aircraft dropping on one, to hit the target on the first mission.)²⁹ The practice actually employed, however, served to maximize sorties flown and bomb tonnage dropped, and it also helped maintain an "acceptable" (or controlled) attrition rate. An alternative approach might have been to assign a given leadcrew

a particular target, to go after it on successive missions until destroyed. Such a harsh incentive could have been sweetened by cash bonuses (or extra leave, or mission credits). The overall effect of such an incentive system would have no doubt been a higher attrition rate per mission, but it could have meant a substantial increase in mission effectiveness.

It is therefore possible that the increased technicalities of armed forces have been accompanied *pari passu* with increased opportunity for negative or perverse combat incentives and, especially in the ground forces, placement of a disproportionate number of people in combat situations who may be either casualty-prone or lacking in combat comparative advantage, or both. Simultaneously, weapons have been designed with little idea of how their technical performance characteristics may provide combat utility. The real war-making production process, as contrasted with the perceived one, is thus a peculiar animal. At a minimum, identification of the combat comparative advantages of people must proceed simultaneously with designing weapons. This same process--which would require very heavy doses of empirical operational research and field experimentation--would necessarily and simultaneously have to address the old-fashioned subject of applied tactics. When these things are done, it is then necessary to design combat incentive systems to motivate the troops and crews. Only then will there be a chance to uncover a relevant production function.

Undertaking a program designed to "find the fighters"--that is, those individuals who possess the composite of skills and ability to perform various functions under extreme stress--would seem to be an effort worthy of high priority. Next, experiments could be conducted to determine, for example, whether a simple or austere system manned by a top individual does as well or better than a sophisticated system operated by a person of lower capability. Entailed in this kind of tradeoff analysis are varying degrees of practice and training, normally costly, because they necessitate equipment operation and

munitions expenditure. The process of testing can, and should, be integrated with testing undertaken to ascertain and specify what the engineering and design specifications of new systems should be.

The Unknown Casualty Prospects

If present day weapons and their associated capital-intensive force structure elements possess an unknown, if not dubious combat utility, productivity and hence the casualty exchange rate will be unknown. Wartime casualty prospects are unknown for a second reason distinct from the uncertainties inherent in production functions and the associated exchange rate. Given whatever exchange rate that does materialize, the total number of casualties that Blue must incur depends on how many Red is prepared to take. Thus if Red is prepared or able to expend 100,000, and if the exchange rate turns out to be 2:1 in Blue's favor, then Blue must expend at least 50,000, plus some "small" increment. *Ex ante*, Red may be willing to expend more or less. But in reality, probably neither Red nor Blue knows what his actual manpower budget might be. As the war goes on, objectives, troop and civilian morale, and the "production functions" change and shift. Thus both the supply price of fighting manpower and the exchange rate shifts further.

This uncertain aspect of casualty behavior arises from the "open-end" nature of warfare. Either the objectives themselves are scaled down, or one side manages to expend most of its manpower in the relevant age groups. One roundabout way by which objectives become "scaled down" but which initially impacts on the exchange rate is through troop behavior itself. As their morale sags, or as troops and crews come to feel that particular missions or assignments are not worth the cost of exposure to risk, they do not pursue their assignments or carry out their missions vigorously. Combat effectiveness falls. In the infantry, this is called "leaning forward in one's foxhole"; with armor, more tanks tend to veer off the road to get stuck in the

mud just prior to presenting one's silhouette on that "last hill"; with aircraft, bombing runs tend to be shortened or the release altitude heightened.

It should be emphasized that these effects are more likely with modern, "capital-intensive" military "production functions." The squad if not the fire team has become the key tactical element and at critical points in operations these very small units are virtually autonomous. Initiative and motivation at these small unit levels are the critical ingredients that determine effectiveness. With crew-served weapons, tanks, and aircraft, the gunner or the commander is the key actor, and the effectiveness of these systems is again sensitive to personal motivation and attributes. One of the consequences of these kinds of behavior is that operational effectiveness and the casualty (or damage) exchange rates become major unknowns but dependent variables that fall out are troop (and crew) motivation and morale.

One of the major consequences of this condition, paradoxically, is that "volunteers"--who are sufficiently motivated--may be a necessity for modern, shooting war. Moreover, these same volunteers should be the individuals with the combat comparative advantage. The situation that characterizes air-to-air combat, in which a very small portion of the pilots ("hawks") shoot down most of the enemy--and, in turn, the majority of the remainder ("doves") are the "meat" for the enemy's "hawks,"--may be equally applicable in land and air forces.³⁰ If one could assume that two or three "hawks" are in each rifle squad, that tank and anti-tank gunners and crew commanders as well as aircraft pilots were so constituted, and that forward observers were people who possess keen target-sensing abilities, then the casualty exchange rate might be drastically changed in a favorable way. We would tentatively estimate that 2000 people per division force, including support aircraft pilots, would nicely cover this requirement. Precisely which specialties should be encompassed within this "fighter category" is a matter that should be the object of further deliberation, including field trials. What the rest of the division force, as well as its

comparable air component "slice" might look like, is wide open. For this reason, incidentally, studies that examine the current force structure (especially in the NATO context), and which make strong statements about support elements being drastically reduced (our S^* component) so as to increase the ratio of *existing* weapons and combat troops, may be somewhat roundabout if not off the mark. Seemingly very high supply prices--including combat performance bonuses--for these key individuals might have to be paid. But the productivity of force elements and hence the overall cost of producing military force might shift in gratifying ways.

Macro-Incentives

Although modern technology poses critical incentive problems at the micro-level of combat, it presents more difficult if not pernicious ones at the macro-level of military decisionmaking. These macro-incentive problems have the unfortunate and important consequence of causing the system not to acquire adequate information on how to design the forces and weapons, and to formulate tactics. As a result we do not really know much about the military production function. Rather, we adhere to the idea that a capital-intensive P describes nature. This may be partly a result of the laudable aim to minimize casualties in war. But this adherence is also compatible with a political model of representative government that places emphasis on procurement and R&D contracts that deliver payrolls to specific locations. Elements of Congress and high political officials in the Executive Branch thus receive the support of grateful constituents, and these officials, in turn, reward administrators with budget approvals and authorizations. The system is made operational by requiring military departments to justify their budgets by detailed line items.

Given this detailed line item budgeting, the incentives impacting upon the military services and their managers are such that most new weapons developed in the United States over the past 25 or so years have been political-budgetary tactics designed to carry out one or more

of the following objectives: (1) maximize the total military budget; (2) aggrandize the services' missions; (3) protect a particular service's or a narrower combat specialty's mission; and (4) preserve the "validity" of self-serving combat doctrine. In some instances, some of these motives are also combined with or superseded by (5) catering to powerful members of Congress who may be friendly in future budgeting deliberations, (6) a desire to keep an "in-house" laboratory or arsenal in business. Sometimes, all these forces might be overridden by the recommendations of outside but influential technologists who, by means of direct access to high-placed officials, successfully advocate what seems to the technologists a technically attractive way to cope with a difficult tactical problem. That a weapon might turn out to be a good fighting instrument is possible, but if it does, the result is more accidental than purposeful. Most of these developments are consummated and quickly procured and fielded by means of large cost overruns. Also, many of the often irrelevant technical performance specifications are not fully met, and there are even time delays in development and subsequent procurement.³¹

Seldom are the technical performance parameters describing most of these conceptual systems subjected to operational tests or similar tactical simulations to determine, e.g., whether Mach 1 plus might be the "optimal" "low altitude" dash capability for an attack aircraft. (Nor is "low altitude" adequately defined, except that it is apparently sufficiently low to warrant, given the speed, a terrain-avoidance radar.) Nor have tests been conducted to determine, as a further example, whether the lower profile of a proposed Main Battle Tank, permitted by an automatic gun loader that eliminates the fourth crewman, provides an increment of combat survivability worth the cost increment or whether the lower silhouette may even degrade combat effectiveness by virtue of reducing crew visibility and hence target acquisition capability.³²

Such conceptual systems, in turn, are generally programmed for development engineering, further programmed for procurement, and often

procured and fielded by means of waivers with respect to troop or crew acceptability in expectation that subsequent retrofits will cope with the unsolved development problems. Sometimes, however, these may take a long time. For example, for a number of years the newly developed M-73 coaxial-mounted machine gun for Army tanks was not reliably operative, and when it did shoot, it required special ammunition lots of U.S. NATO "standard" 7.62mm ammunition. The main consequence of this particular shortcoming was that U.S. Army battle tanks were inadvertently converted to tank-destroyers, because tanks without a coaxial machine gun cannot adequately cope with enemy infantry or provide covering machine gun fire for accompanying foot infantry who are also necessary to protect tanks from unfriendly infantry. (All the while, the Marine Corps stuck to the .30 cal. Browning machine gun for its tanks.)

This behavior pattern of the U.S. weapon development and acquisition process exemplified here has a number of diverse "causes" which come to a head in the macro-budgeting process. One seemingly plausible motive is to try to find ways to substitute capital for labor in war. However, the macro-budgetary incentives are such as to permit the motives described earlier to drive the process. Given the pervasiveness of this budgetary-political-mission aggrandizement--and related motives, which spawn the creation of military "capital goods" and an increasingly "capital intensive" force structure--the idea of substituting more of this kind of "capital" for labor verges on the banal if it were not a bad joke. Indeed, the concept of a "production function" in this framework acquires some peculiar properties. Whatever exists that might warrant that term is not 100 percent relevant to war and foreign policy. Although there may be many opportunities to substitute capital for labor, there is limited, if virtually no, knowledge on how to go about doing it. Conversely, there appears to be knowledge on how to substitute labor in war for capital goods that fall short of expectations or do not work. However, this may entail casualties that greatly exceed expectations.

In such an event, the supply price of manpower rises sharply (as evidenced by campus riots). To try to substitute more of the same kind of capital goods to mitigate this situation or to implement the idea of an all-volunteer armed service would seem to be an approach that possesses flaws.

At best, it might be wise to accept initially the idea that there is "no such thing" as a well-defined production function applicable to the fighting side of military affairs in a setting where a mindless bureaucracy appears driven by a mindless technology, but where the process nevertheless "makes sense" if the "missions" (outputs) and the capital inputs are specified in such a way as to wage bureaucratic and budgetary rather than real war. The negative implications of this assertion are that most new weapons are secondarily means with which to conduct military operations.³³ At most there is a "perceived," capital-intensive production function. Whether the real, war-fighting production function is labor- or capital-intensive is anybody's guess.

The extent to which technological change can induce shifts in the production process is even more uncertain in a setting where it is pursued and promoted without adequate knowledge about fine-grained anatomy of combat. To acquire the latter information requires extensive and rigorous operational testing. Unfortunately, such testing can reveal that a new gadget or idea does not work very well under field conditions and in the hands of troops. Hence, a future planned procurement might be jeopardized. Thus, there is a negative incentive to do much testing. The price of this condition is an information failure that attenuates ability to take advantage of new technology, and excessive casualties in war that are likely to be a consequence of that information failure.³⁴

Appendix A

MEASUREMENT OF LAND FORCE MANPOWER USAGE:
THE DIVISION YEAR AND OTHER MEASURES

In Table 1 of the text, the metric "division-year," along with casualty data, is employed to make some broad comparisons as between recent United States land wars. This appendix provides the information building blocks from which the division-year estimates were made.

Table A-1 provides a detailed breakout, by year and as between Army and Marine Corps, of estimated division-year employment in Indochina. For these calculations, an independent brigade or attached regiment was assumed to be one-third of a division. For the period of 1965 through June 1968, estimates of the number of months for each brigade or regiment were obtained from Source (2) cited in Table A-1. These data are provided in Table A-2. For the second half of 1968, it was assumed that all brigade or regimental units listed in Table A-2 were present in the Theater. It was also assumed that all (or equivalent) Army units were in the Theater during 1969. For 1969 for the Marine Corps and for 1970 for both the Army and Marine Corps, division estimates were scaled down from the June 1968 level as shown in Table A-2 in proportion to troop strengths as shown in Table A-1. In all these calculations, three regiments or brigades were assumed equal to one division.³⁵

Derivation of the division-year estimate for U.S. Army forces in Korea between July 1950 and July 1953 is presented in Table A-3. From the period early 1951 onward, there were roughly six and two-thirds U.S. Army Divisions in Korea. Overall, however, some eight divisions and 28 regiments, including regimental combat teams, were employed at various times in Korea. Average regimental strength was 3457; number of regiment days was 20,568.³⁶ If this regiment day figure is divided by 365, to derive 56.5 regiment years, and the latter figure is divided by three, the result is 18.33 division years. This 18.83 figure is probably closer to the mark than the 19.5 figure shown in Table A-3. However, the method of derivation shown in Table A-3 more closely compares to the method employed to estimate Indochina division employment.

Table A-1

DERIVATION OF U.S. DIVISION FORCE ESTIMATES, INDOCHINA WAR, 1965-1970

Year	Average Troop Strength (000)		Division-Year Equivalent		
	Army	Marine	Army	Marine	Total
1965	51.2	20.8	1.06	.75	1.81
1966	178.1	53.7	3.94	1.89	5.83
1967	279.4	73.6	6.64	2.25	8.89
1968	351.4	78.0	8.30	2.64	10.94
1969	352.3	73.9	8.33	2.25	10.58
1970	298.5	37.1	7.03	1.24	8.27
Total			35.3	11.02	46.32

SOURCE: (1) Directorate for Information Operations, Office, Secretary of Defense (Tabular Release), "U.S. Military Personnel in South Vietnam," n.d.

(2) W. C. Westmoreland, Report on the War in Vietnam (as of 30 June 1968), I: Report on Operations in South Vietnam, January 1964-June 1968, U.S. Government Printing Office, Washington, D.C., n.d., especially pp. 275-278.

METHOD: Average troop strength estimates are derived by taking the average of beginning- and end-of-year strengths for the years 1966-1967; quarterly figures for 1968; and monthly figures for 1969 and 1970, as given in Source (1). For 1965, Source (1) end-of-year strengths were averaged with strengths given in Source (2), passim, for March, May, and October.

Division force estimates were derived from Source (2) which gave arrival dates in Theater by month of Brigades and Regiments through June 1968. The Brigade or Regiment "months" were added for totals (these are shown in Table A-2 below); and allocated to each year; and divided by 36 to estimate "division years." A Brigade or Regiment was reckoned to be one-third of a division. All Brigades or Regiments in the Theater as of June 3, 1968 were assumed to be in the Theater for the remaining six months. Maximum division force for the Army was 8.33; for the Marine Corps, 2.66. For 1969-1970 for the Marine Corps and 1970 for the Army, the latter figures were scaled down in proportion to troop strength reduction relative to 1968 to estimate division force strength.

Table A-2

U.S. LAND FORCE EMPLOYMENT IN INDOCHINA, 1965 TO JUNE 1968
BY BRIGADE OR REGIMENT

Unit	Arrival Date	Brigade or Regiment Months to June 1968
<u>ARMY</u>		
1st Infantry Division		
1st Brigade	October 1965	33
2d Brigade	July 1965	36
3d Brigade	October 1965	33
1st Cavalry Division		
1st Brigade	September 1965	34
2d Brigade	September 1965	34
3d Brigade	September 1965	34
4th Infantry Division		
1st Brigade	October 1966	21
2d Brigade	August 1966	23
3d Brigade	December 1966	19
9th Infantry Division		
1st Brigade	December 1966	19
2d Brigade	January 1967	18
3d Brigade	December 1966	19
23d Infantry Division		
11th Light Infantry Brigade	December 1967	9
196th Light Infantry Brigade	August 1966	23
198th Light Infantry Brigade	October 1967	9
25th Infantry Division		
1st Brigade	April 1966	27
2d Brigade	January 1966	30
3d Brigade	October 1966	21
101st Airborne Division		
1st Brigade	July 1965	36
2d Brigade	December 1967	7
3d Brigade	December 1967	7
173d Airborne Brigade	May 1965	38
199th Light Infantry Brigade	November 1966	20
3d Infantry Brigade		
Task Force, 82d Airborne Div.	February 1968	5
11th Armored Cavalry Regiment	September 1966	22
Total Army		577
<u>MARINE CORPS</u>		
1st Marine Division		
1st Marine Regiment	February 1966	29
5th Marine Regiment	April 1966	27
7th Marine Regiment	August 1965	35
26th Marine Regiment	April 1967	15
27th Marine Regiment	February 1968	5
3d Marine Division		
3d Marine Regiment	March 1965	39
4th Marine Regiment	May 1965	37
9th Marine Regiment	July 1965	36
Total Marine Corps		223

SOURCE: W. C. Westmoreland, Report on the War in Vietnam, II: Report on Operations in South Vietnam, January 1964-June 1968, U.S. Government Printing Office, Washington, D.C., Appendix J, pp. 275-278.

Table A-3

U.S. ARMY DIVISION (AND SEPARATE REGIMENT) EMPLOYMENT IN KOREA,
JULY 1950 THROUGH JULY 1953

Unit	Arrival	Departure	Div. Years
24th Infantry Division	2 July 1950	4 Feb. 1952	1.58
1st Cavalry Division	18 July 1950	30 Dec. 1951	1.46
25th Infantry Division	9 July 1950	--	3.08
2d Infantry Division	30 July 1950	--	3.00
5th Regt'l Combat Team	3 Aug. 1950	--	1.00 ^a
187th Airborne Regiment	17 Sept 1950	27 June 1951	.26 ^a
	12 May 1952	17 Oct. 1952	.14 ^a
	22 June	--	.03 ^a
7th Infantry Division	18 Sept 1950	--	2.88
3d Infantry Division	10 Nov. 1950	--	2.83
45th Infantry Division	5 Dec. 1951	--	1.66
40th Infantry Division	11 Jan. 1952	--	<u>1.58</u>
Division Years			19.50

SOURCE: Frank A. Reister, op. cit., p. 1.

^a Regiments assumed to be equal to one-third of a division.

The basic data for the World War II division-year estimates in the three major European efforts are shown in Table A-4. Data in the source, however, were provided in terms of average manpower strengths for the different types of divisions. Our calculus to derive division-year equivalents employed authorized TO&E strengths. Since divisions are seldom at full strength, our estimate of division-years is likely to be slightly on the low side and our estimates of casualties per division-year will be slightly higher than those derivable from a more refined estimate.

Casualty data shown in text Table 1 are those reported as killed and wounded during the period of conflict. They do not include "missing and captured." For World War II in Europe, this latter category constituted about an additional 14 percent. Table A-5 provides this more inclusive data for World War II, European experience.

U.S. Army Korean War casualties were:³⁷

Killed in action	19,353
Wounded in action	77,788

The comparable estimate for Indochina is developed in Appendix B.

Table A-4

TROOP STRENGTHS AND DIVISION YEARS, WORLD WAR II:
NORTHWEST EUROPE, ITALY, AND SICILY

(1) Campaign	(2) No. of Days	(3) Estimated Average Strength (Thousand)	(4) Division Year Equivalent
Northwest Europe	337		
Division			
Infantry		346.3	24.7
Armored		96.5	9.0
Airborne		25.2	1.8
All types		<u>468.0</u>	
Corps		218.1	
Army		218.2	
Total, Northwest Europe		<u>904.3</u>	<u>35.5</u>
Italy	608		
Division		90.5	11.2
Army		182.8	
Sicily	39		
Division		100.3	1.1
Army		183.5	
Total			47.8

SOURCE: Columns (1), (2), and (3) from Gilbert W. Beebe and Michael E. DeBakey, Battle Casualties: Incidence, Mortality, and Logistics Considerations, Charles C. Thomas, Springfield, Illinois, 1952, Table 15, especially pp. 52, 54. Column (4) was derived by dividing T.O. troop strengths into "division" figure, and adjusting the result by the proportion of the days shown in Column (2) to 365 days. Division strengths used were: Armored, 10,670; Infantry, 14,037; Airborne, 12,979. These were authorized strengths and were taken from Kent Roberts et al., United States Army in World War II: The Army Ground Forces: The Organization of Ground Combat Troops, Historical Division, Department of the Army, Washington, D.C., 1947, pp. 306, 320, 349. For Sicilian campaign, one airborne and one armored division was assumed, the remaining force infantry; for Italian campaign, one armored division was assumed to derive the division year estimates.

Table A-5

LAND FORCES COMBAT CASUALTIES, WORLD WAR II, EUROPEAN THEATER

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Campaign	Killed	Wounded	Total	Division Years	Casualties per Division Year	(Casualties per Division Year, including Missing and captured)
Northwest Europe	89,268	373,202	462,470	35.5	13,064	(14,792)
Italy ^a	29,665	95,612	125,277	11.2	11,185	(13,486)
Sicily	1,439	5,236	6,675	1.1	6,068	(7,082)
Total	120,372	474,050	594,422	47.8	12,436	

SOURCE: Beebe and DeBakey, op. cit., pp. 53, 55.

^aIncludes Southern France to October 1944.

It should be emphasized that the Division-Year measure employed here is an aggregative measure. It should not be used without some idea of the size of a division, and especially its composition as between various combat and service specialties that make up the different kinds of divisions. It should be even more forcibly emphasized that casualties are distributed very unevenly as between different components and specialties that compose a division and a field army. For this reason, casualties per division-year (or division day), as well as per regiment or even battalion, are themselves aggregations. Ideally, casualties should be related to such a base as "per 1000 men per day" by organization and by military specialty. The latter measure, however, requires data on unit *actual* strengths, which themselves are highly variable with regard to smaller units, because of the nature of casualty behavior. These refinements are yet to be made for the Indochina War.

Appendix B

THE ANALYSIS AND INTERPRETATION OF CASUALTY DATA

In the text discussion centering around Table 1, an "estimated and adjusted" figure of 235,365 is shown for U.S. ground forces (Army and Marine Corps) casualties in Indochina for the years 1965-1970. The officially reported casualty total for the same period for the Army and Marine Corps from which this estimate was derived was 321,164. One objective of this paper was to make some general comparisons about casualty behavior as between various U.S. wars. However, for purposes of making such comparisons, the casualty data released for the Indochina war appears to overstate "casualties," compared to data on past wars. This overstatement centers around the category of "wounded."

Although casualty data are in certain ways perhaps the "hardest" information available about war and military affairs, they also contain certain elusive qualities. Even though this point is well understood by many students, it warrants more general appreciation. In the above text some general questions were posed about the "meaning" of casualties as an aspect of attempting to apply the analytic concept of a production function to defense management. Analysis of casualty data may provide some insights about some of these questions. However, casualty data contain and present a number of fine-grained questions that are troublesome in their own right. Appreciation of this aspect of casualty data appears useful if one seeks to use those data to analyze war and other elements of military management. The difference between 321,000 and the 235,500 figure cited above highlight this point.

This Appendix develops the rationale for adjusting the official statistics on casualties due to hostile action during the period of 1965-1970, to arrive at the 235,500 figure used in Table 1. It also tries to provide some general information about wartime casualty data that may be useful to integrate such information.

Table B-1 shows reported total casualties due to hostile action for each of the Military Departments for the 1965-1970 period, as tabulated and released by the Office of the Secretary of Defense. The table also shows deaths due to other causes, which include those resulting from illness or "normal" mortality--e.g., strokes and heart attacks, as well as accidents, suicides, and so on. Some of these latter deaths, as well as nonfatal injuries or disease cases, although not "caused" by hostile action, may in certain ways be related to military operations. Or at least there are correlations between the two major categories that are relevant or useful for certain aspects of manpower management.

Table B-1

TOTAL REPORTED CASUALTIES DUE TO HOSTILE ACTION AND
DEATHS DUE TO OTHER CAUSES, SOUTH VIETNAM,
BY MILITARY SERVICE AND TYPE, 1965-1970

Cause	Army	Marine Corps	Navy	Air Force	Total
Due to hostile action					
Deaths	28965	12873	1353	791	43982
Wounded	191334	87922	13665	2875	295796
(Hospitalized)	(91429)	(51020)	(3984)	(722)	(146156)
Total	220299	100795	15018	3666	339778
Other deaths	6025	2433	798	504	9760

SOURCE: Directorate for Information Operations, Office of Secretary of Defense, release entitled "U.S. Military Personnel in South Vietnam."

"Deaths" as a casualty category is quite unambiguous.³⁸ It is the "wounded" category that is troublesome. Notice in Table B-1 that slightly over half of the total wounded were *not* "hospitalized." Tables B-2 and B-3 provide further detail on deaths and wounded for the Army and Marine Corps. Notice the 321,163 figure for total casualties in Table B-2. It was this total that was adjusted to 235,536 that is

Table B-2

REPORTED ARMY AND MARINE CORPS BATTLE CASUALTIES, 1965-1970

Year	Army		Marine		Combined Army and Marine		Total Casualties
	Killed	Wounded	Killed	Wounded	Killed	Wounded	
1965	898	3,639	335	2,000	1,233	5,639	6,872
1966	3,073	18,574	1,638	10,310	4,711	28,884	33,595
1967	5,443	33,573	3,452	25,525	8,895	59,098	67,993
1968	9,333	59,838	4,618	29,269	13,951	89,107	103,058
1969	6,710	50,543	2,254	16,612	8,964	67,155	76,119
1970	3,508	25,194	533	4,275	4,041	29,469	33,510
Total	28,965	191,361	12,830	87,991	41,795	279,352	321,147

SOURCE: Directorate of Information Operations, Office of the Secretary of Defense, n.d.

Table B-3

COMPOSITION OF NON-FATAL WOUNDED, ARMY AND MARINE CORPS,
INDOCHINA, AND DERIVATION OF "ADJUSTED" ESTIMATE OF
WOUNDED AND TOTAL CASUALTIES, 1965-1970

Year	Army		Marine Corps	
	Hosp.	Non-Hosp.	Hosp.	Non-Hosp.
1965	1965	1674	1241	759
1966	10030	8544	6186	4121
1967	18271	15302	13088	12437
1968	27405	32433	17833	11436
1969	21811	28732	9890	6722
1970	11947	13247	2782	1493
Subtotals	91429	99932	51020	36971
Total wounded	191,361		89,991	
Percent Hosp.	47.8		56.7	
68% total wounded	130,125		57,632	
Deaths	28,965		12,830	
Adjusted casualty estimate	159,090		70,402	
Total			229,492	
(Ratio of deaths to hosp. wounded)	(.317)		(.251)	

SOURCE: Directorate for Information Operations, Office of the Secretary of Defense.

presented in Table 1 of the text. Since the text made some comparisons between Indochina and past U.S. wars, it was necessary to deflate or adjust downward the wounded category as reported for Indochina.

Before laying out the rationale for the specific adjustment, it may be useful to point out some aspects of casualty reporting and data as it relates to land forces.³⁹

In armies, battle casualty reporting and the data it produces is carried out by two separate entities: the Adjutant General (or similar personnel accounting entity), and the Medical Service.⁴⁰ The Adjutant General's focus is on personnel records for purposes of keeping track of individuals and, particularly, unit strength. The Medical Service maintains medical records, and the data from these are relevant to medical workloads and logistics, including echelonment of medical facilities, evacuation policy, and the design and manning of medical units.

A characteristic of any nonfatal medical case (including disease or illness) is that it can range from an incident that does not impair an individual's ability to perform his work to one that is completely incapacitating. It is similar with battle wounds. But the concept of "incapacitation" is itself relative to the kind of work an individual does, or an organization's mission. In military organizations, the medical "work load" that results from operations varies markedly, both through time and as between similar and different kinds of organizations. Any military unit that has administrative (as compared with purely tactical) capability also has some organic medical resources.⁴¹ But the amount of medical capability organic to any unit, like a battalion or division, can vary as determined by organizational design, and hence there can be differences in unit medical capability as between services (e.g., Army and Marine Corps; U.S. and Soviet armies), and over time. These variables can interact in complex ways to affect casualty reporting and statistics.

To illustrate some of these interactions, it is useful to examine the focus of the Adjutant General as compared to that of the Medical

Service. Toward the end of World War II the definition of a "wounded" case from the Army's Adjutant General's viewpoint referred to one which entailed a loss of one day (or more) of an individual's availability to his unit. The Morning Report count was the relevant measure. This meant, roughly speaking, that if a man was hit but cared for in his battalion or divisional medical facility, he might not be classified as wounded in the Adjutant General reporting system. In effect, he was still under the "control" of his unit, and was regarded as available for duty should the need arise. This method of accounting, therefore, ruled out reporting as wounded those minor cases that could be taken care of by a bandage and an aspirin. But it could also exclude some of the more serious cases whereby a man could receive a form of outpatient treatment from his battalion or squadron surgeon but be permitted to recuperate in his quarters.⁴² The outpatient treatment could also be obtained from a nearby hospital. For the more serious cases treated by the outpatient method, the Medical Service (including those organic to tactical-administrative units) established and maintained records. Accordingly, the Medical Service's record and tabulation of wounded cases exceeded that of the Adjutant General. By the end of World War II and during the Korean War there emerged a Medical Service category called "Carded for Record Only" (CRO) to measure this work load. It would usually but not necessarily exclude minor wounds.

During most of World War II and at the very beginning of the Korean War, there was also some ambiguity in Adjutant General reporting. In some units, cases treated in a unit's medical facility were reported through command channels and were interpreted as "unit losses," even though the incidence of some of these may have been minor. During the Korean War, the term "admission" as applied to medical cases referred to one where the individual might be either hospitalized or treated on an outpatient basis when the individual remained with his unit but was excused from duty. In the latter instance, the Adjutant General report was supposed to report the loss of availability for duty.

A "CRO" case entailed a medical workload and report, but no Adjutant General accounting of loss of unit strength.

For the Vietnam war, a dichotomy of "hospitalized" and "non-hospitalized" wounded was instituted by the Office of the Secretary of Defense. It apparently became a policy to require that all wounded cases be reported through command channels--to extend to minor ones many of which, during past wars, would not even have been carded for record. Yet some of the nonhospitalized wounded were cases that entailed a loss of time and required treatment in a medical facility (as contrasted with a hospital). Accordingly, the Army Surgeon General estimates that 32 percent of its total, reported by OSD as wounded, were "so minor that they could be treated and returned to duty immediately without admission to a medical treatment facility."⁴³ On the basis of this 32 percent factor, it can be estimated that 68 percent of the total casualties reported as wounded in Indochina compares with those reported for Korea and World War II when the non-CRO (as reported for Korea) category is excluded.⁴⁴ For our purposes, the same factor was also applied to the reported total wounded of the Marine Corps.

Applying the 68 percent factor to the Marine Corps' total wounded may not be appropriate. However, such analysis should be very carefully conducted. One should not conclude, for example, that because the Marine Corps had a larger portion of its wounded hospitalized the overall incidence of its wound casualty experience was more severe or "serious." Nor should it be concluded that the Marines had a more lax policy for admitting men to a hospital. (Both Table B-1 and B-3 indicate that a larger portion of Marine Corps wounded were admitted to hospitals than was the Army's.)

In adjusting the Marine Corps count of wounded to make them comparable to the Army's, one can employ either of two techniques. First, one can assume that both services employ a similar criterion for "wounded" (which they do), and that the Army's experience with "minor" wounds would also apply to the Marine Corps. (This method is

adopted here, and is shown in Table B-3.) Another approach is to assume that both the Army and the Marine Corps employed comparable criteria for hospitalizing their wounded, but that the Army was more "generous" in recording (and crediting) minor wounds. This method was rejected in making the overall estimate.

The reason for rejecting the second method is that examination of the ratio of deaths to hospitalized wounded would then suggest that the Army experienced an overall more serious incidence of casualties as between deaths and "seriously" wounded, as compared to the Marine Corps. (The bottom of Table B-3 shows that the Army's ratio of deaths to hospitalized wounded was nearly 32 percent as compared with 25 percent for the Marine Corps.) This great a difference does not seem credible. Rather, it is likely that a larger portion of the Marine Corps' wounded were hospitalized, for two reasons. The most important reason was that the Marine Corps was involved in relatively more small unit operations, such as long-range patrolling, than were Army units. Under these conditions, a casualty evacuated by helicopter was likely to be transported to a hospital. With the larger brigade and division size Army operations, wounded--although also evacuated by helicopter--were more likely to be deposited first at a division clearing station, where some may be retained or permitted to retire to quarters for recovery. It is also likely that the Marines employed a liberal evacuation policy during the Khe Sahn operation in order to minimize the number of people in division medical facilities when they would be vulnerable to random incoming artillery rounds.⁴⁵

The adjustment of the total wound count employed here therefore assumes that the ratio of deaths to nontrivial wounds was about the same for the Army and Marine Corps. This assumption, however, is a hypothesis that warrants critical examination because it is well-known that the incidence of battle casualties also varies as a function of the type of operation and instrumental causes of casualties. Moreover, there are some elements of multicollinearity between instruments of casualties and different types of operations. For example, a gunshot

or bullet wound is more lethal than a fragment wound (artillery, mortars, or grenades).⁴⁶ Attacks against well-defended positions where an enemy has been able to register his artillery and mortars produces relatively more fragment wounds than does pursuit against a retreating enemy where the opposition is mainly designated rifle or machine gun squads. Defense of static positions facilitates wearing protective vests, which reduces greatly the wound incidence of fragment hits but which does little to lessen injury from bullet wounds. (Indeed, a bullet hit may be rendered more lethal by an armored vest.)⁴⁷ However, it is difficult to get troops (despite "command policy") to wear six to eight pounds of protective clothing on extended dismounted operations, especially in hot weather, and when the mission requires being loaded down with several hundred rounds of ammunition, a couple of canteens, rations, and so on. Hence a number of variables affect both the incidence and mortality of battle wounds.

Tables B-4 and B-5 provide some limited information about the anatomy of Indochina battle casualties. These tables treat deaths only. Table B-4 shows the breakout between air crews and ground troops.

Table B-4

DEATHS DUE TO HOSTILE ACTION, BY SERVICE AND TYPE OF ACTION,
INDOCHINA, THROUGH MARCH 1973

Cause	Army	Marine Corps	Navy ^a	Air Force	Total
Air Action					
Air crews only					
Fixed wing	52	66	168	744	1030
Helicopters	1752	295	53	64	2164
Subtotal	1804	361	221	808	3194
Non-aircrew	704	214	23	43	984
Ground	28087	12361	1126	150	41724
Sea			56		56
Total	30595	12936	1426	1001	45958

SOURCE: Directorate for Information Operations, Office of the Secretary of Defense.

^aIncludes five Coast Guard personnel.

Although Army and Marine Corps helicopter crew casualties might, in a sense, still be regarded as "ground casualties," their nature differs from casualties taken on the ground. Table B-5 provides some detail on the "instruments" of battle deaths. Of particular relevance in this table is the breakout between deaths caused by small arms and fragmenting munitions. Given the higher lethality of bullet wounds, support would be given to the idea that the service (or unit) which, by the nature of its operations, incurs a higher proportion of bullet wounds would also experience a higher mix of more seriously wounded surviving casualties. Stated another way, if one service experienced 20 percent of its casualties from bullet wounds, and another service experienced 40 percent, the service with the 40 percent ratio would (1) have a higher ratio of deaths to total casualties, and (2) its surviving wounded would, on the average, be more seriously wounded. No such line of argument can be supported by the evidence in Table B-5.

Table B-5

"INSTRUMENTAL" CAUSE OF CASUALTIES (DEATHS ONLY) BY
HOSTILE ACTION, INDOCHINA, THROUGH MARCH 1973

Cause	Army	Marine Corps	Navy	Air Force
Air crash ^a	2508	575	244	851
"Ground action"				
Small arms	12327	5638	398	22
Fragmenting munitions ^b	13852	6185	653	125
Other causes ^c	1345	501	106	3
Total, ground	27524	12324	1101 ^d	150
Percent, small arms	44.8	45.8	36.1	14.7

SOURCE: Directorate for Information Operations, Office of the Secretary of Defense.

^aFigures shown for "air crash" do not coincide with those under "air crews..." shown in Table B-4 (and which are air crewmen only). The main difference between the two totals is some 984 "non-aircrew" personnel (of which 704 were Army and 214 were Marines) who were "air casualties" but not air crewmen. (Of this 918 Army and Marine total, 820 were on helicopter flights.) Most of this subset of "air casualties" is therefore ground troops going to or coming from operations.

^bThis category is an aggregation of four categories given in source. They are "artillery/rocket," "bomb explosion," "other explosion (grenade/mine)," and "multiple fragmentation wounds." "Bomb explosion" was minor, totaling only 50 for all services. All four categories are characterized, as instruments of wounds, as "fragmenting munitions" even though they produce casualties by their blast effect as well as by issuance of fragments.

Such classifications as "artillery/rocket," and so on, can be potentially misleading as tools of operational analysis or weapon system evaluation. For example, does it also include mortar-caused casualties? It probably does since very careful operational research in the field is necessary to get even a rough (but highly useful) estimate of the casualty-producing capabilities of artillery, rockets, mortars (and air dropped munitions) under different tactical conditions. That this official four-fold classification is of limited use is further suggested by the point that 8465 of the total of over 21000 in our aggregation was in the "multiple fragmentation wounds" category. As such, it provides no insight as to the precise instrument of wounding; it also suggests that other deaths attributed to artillery, mines, and grenades, were caused by a single fragment, or by blast, which is unlikely.

^c"Other causes" in our table is an aggregation of "vehicle loss/crash," "drowned and suffocated," "burns," and "misadventure." Of these, "misadventure" is the dominant item, accounting for 1318. The word is bureaucratese for foul-ups that are an inevitable part of operations. Judging from its magnitude, it would seem to include the known consequences of fire fights between friendlies, stumbling into one's own artillery fan, premature bomb releases, and so on. It is likely that the "small arms" and "fragmenting munitions" categories contain some of this same element.

^dIncludes four Coast Guard personnel.

THE CAPITAL-INTENSIVE MILITARY PRODUCTION
PROCESS AND PERVERSE INCENTIVES

Endnotes

1. The rough quality of these estimates should be emphasized. Much centers around the definition of an "infantryman" and a "combat vehicle." If by "infantryman" one means those who bear the heaviest casualty incidence of fighting, and particularly those in rifle platoons, who might be categorized as "combat infantry," the 6500 figure given in the text may be on the high side. United States Army infantry battalions (non-mechanized) have three rifle companies with three rifle platoons each (44 men) plus a weapons platoon (36 men), for a company strength of 180. Most Army battalions sent to South Vietnam, however, possessed a fourth rifle company, which brought total rifle company authorized strength up to 720 per battalion. Most infantry divisions possessed nine infantry battalions. Marine Corps battalions have a normal authorized strength of around 1200 men (as compared to the Army's three-rifle company, 829-man battalion) with much of the difference being in rifle platoons due to the Corps' 14-man rifle squad as compared to the Army's 10-man rifle squad. In addition, each battalion headquarters company possesses a scout platoon and assorted crew-served heavy weapons. Consideration of these diversities led to postulating the 6500 infantrymen-per-division figure. (This number would be lower in Europe where divisions possess more tank battalions and fewer infantry battalions, each with three rifle companies.) The 200 "combat vehicle" figure takes into account that an Army nine-infantry-battalion division also possesses a tank battalion with an authorized 54 tanks. The average number of helicopters per division in South Vietnam approached perhaps 400; however, not all of these should be reckoned to be combat vehicles in the strict sense of the word. Also, armored personnel carriers were used in a combat role that was perhaps unique to that war.
2. *Department of the Army Field Manual FM101-10*, January 1966, pp. 4-29, gives a figure of 43,250 for a World War II theater "division slice." This figure includes Communication Zone troops for an overseas deployment of 89 divisions. The comparable "Worldwide Division Slice" was 63,250, which included troops in transit and those in the United States. These figures do not include the World War II theater "Air Force Wing Slice" of 7000, which contained an average of 1000 Army Communication Zone troops. During World War II, the Marine Corps had a peak personnel strength of around 475,000, which provided six specialized

infantry divisions plus air elements, which suggests a worldwide "division-air-wing slice" of about 80,000. In addition, the Marine Corps obtained much overhead support from the Navy. During the Korean War, the U.S. Army had about 6-2/3 divisions and a theater troop strength of around 230,000 men by the spring of 1951, a "division slice" average of 35,600. In South Vietnam, the comparable figures were 11 divisions (8-1/3 Army; 2-2/3 Marine Corps) and 440,000 troops.

It should be pointed out that in the last two wars, the United States extensively employed indigenous civilians for many support functions. But the same logistics apparatus (mainly operated by the Army as contrasted with the Marine Corps) supported non-U.S. troops such as the South Vietnamese, South Korean, and lesser allies. "Division slice" figures therefore reflect these and other variables.

3. Some readers have concluded from Table 1 that there is a sharp "downward trend" in the casualties per division-year. It should be pointed out that the Sicilian Campaign occurred in July-August 1943, the Italian Campaign began in September 1943 and lasted until May 1945, and Northwest Europe was from June 1944 until May 1945.

As between World War II and the subsequent wars there is simply a downward "step," the meaning of which is unclear. One interpretation is that in the latter wars we did not achieve a "decisive outcome." Another is that we used materiel (munitions) and capital more lavishly, and that we achieved a more favorable casualty exchange rate. The latter assertion is difficult to verify because of unclear evidence about enemy casualties. One should not take at face value published reports of these, which in the case of Indochina appear to be about 6:1. We would place it at about 1.5, or 2:1. (By "exchange rate," incidentally, we exclude prisoners for reasons discussed in the text.)

4. The design of an item extends beyond technology, even though technical change permits new designs. Good design entails perception of the function or job that the contrivance is to perform. Hence the designer must blend knowledge of diverse engineering or technical fields with an understanding of the environment in which the item will be used, to include the behavior of the users themselves. With regard to weapons it is difficult to achieve this blending because those possessing engineering expertise seldom have opportunity to directly observe the behavior of systems in use in actual combat. Conversely, military "users" do not always directly communicate with the designers. Rather, the user role is expressed by senior officers whose actual combat experience in the foxhole, turret, or cockpit may have been nonexistent or many years removed from the present.

5. Karl von Clausewitz, *On War*, translated by O. J. Matthijs Jolles, Modern Library, New York, 1943, pp. 237-244.
6. Ibid., p. 238.
7. Ibid., p. 239. The ratio of men to guns in the artillery was about 12 to 15 men per gun.
8. Ibid., pp. 240-241. The latter ratio was evident in Napoleon's armies.
9. Ibid., p. 244.
10. However, then the men could fight on foot, and the horses served primarily as an infantry personnel carrier. This was the prevalent cavalry tradition in the U.S. Army, as contrasted with European. This sub-branch of horsemen was termed "Dragoons" (and the first U.S. cavalry units were so labeled). However, in most European circles, the Dragoon specialty was held in low repute. In theory, they were to "blend" the best qualities of cavalry and infantry. It was contended by many, however, that they could not stand up to bona fide horsemen in a mounted fight. As infantry, they had disadvantages if only because some of them (usually one out of three) had to hold the horses. However, Union cavalry--fighting dismounted but moving by horse--turned the flank at Petersburg, which led to the fall of Richmond. That they had repeating rifles also contributed to this success.
11. Ibid., p. 179.
12. The same point also extends to air and naval war. In air war, trained crewmen (entailing a large capital investment) become the critical limiting factor. In naval war, ships (with their long construction lead times) and crews to a lesser extent are critical. Total manpower casualties are not large as compared to land war. However, air and naval battle casualties can be extremely intense for the relatively small number of combat personnel involved. For example, when *Hood* was sunk by *Bismarck*, only three of *Hood*'s crew of 1419 survived. Submarine war also entails a distinct "batching" of manpower losses.
13. This had occurred by around 1600, and, combined with metallurgical improvements that permitted "ship-killing" cannon, the emergence of true naval warfare and tactics took place. In ancient through medieval times, serious war at sea was essentially infantry warfare, and generals commanded the troops and the operations. Coastal raids and piratical undertakings were also major activities involving the use of ships, and enterprising civilians could usually follow these callings quite effectively. However, sovereigns began to establish and assert feudal claims against these particular subjects. This seems to be the reason the Royal Navy never had an official day of its founding.

14. Alfred Thayer Mahan, *The Influence of Sea Power Upon History, 1660-1783*, Hill and Wang, New York, 1957, p. 1.
15. More accurately, it was Lenin who refined the Marxian model to encompass foreign "Imperialism" as a mechanism by which the "capitalist engine" could partially avert a declining rate of profit--including increasingly intensive business cycles, unemployment, and "misery of the proletariat"--which would delay the eventual collapse of capitalism. Foreign markets and sources of cheap raw material could offset an otherwise diminishing return to capital, given capitalists' propensity to re-invest their profits. Also part of this model was the idea that rival capitalist powers would engage in war with each other to secure these markets for their respective exploitation.

Thus a case can be made that Mahan was a "Marxist," or that Lenin could have cited Mahan to buttress his theory of Imperialism.

This Mahan-Marx-Lenin model has had rough going. From a narrow military viewpoint, an argument can be made that Mahan exaggerated the importance of naval operations in the wars during the period he treated, including the British-French phase of the 1775-1783 "American War." A strong case is also made that colonial holdings were more of a burden than a benefit to nations that acquired them, and that "free trade" and international specialization were the relevant external source of capitalist progress. As for "colonial exploitation" instances can be found which suggest that any exploitative nexus--if it existed--was one whereby the taxpayers of the mother (or metropolitan) country were taxed to support a colonial apparatus that benefited specific mother-country pressure groups.

16. Sir John Moore, quoted in Philip Guedalla, *Wellington*, Harpers, New York, 1931, pp. 169-170.
17. A partial indication of this point is suggested by the following figures showing population, numbers engaged in battles, killed and wounded, by decade, for France and Britain, for the decades 1790-1820:

Decade	Population	No. Engaged	Casualties	% Population
- France	(000.000)	(000)	(000)	casualties
1790-1799	27.5	4748	407	1.48
1800-1809	29.3	3065	327	1.19
1810-1819	30.5	3782	470	1.54
- Britain				
1790-1799	10.4	333	24	.23
1800-1809	11.8	225	15	.13
1810-1819	14.0	410	52	.37

SOURCE: Quincy Wright, *A Study of War*, Vol. 1 (Chicago: University of Chicago Press, 1942), pp. 658, 660.

18. Ibid., p. 662, shows for the United States, during the Civil War decade, 1860-1869:

Population (000.000)	No. Engaged (000)	Casualties (000)	% Population casualties
38.6	3995	496	1.29

Comparable casualties as a percent of population for the World War I decade were:

Britain	2.61
France	5.63
United States	.14

However, U.S. World War I casualties are deceptive. Total killed and wounded, shown by Wright, were 150,248. About 120,000 of these were taken during the last six weeks of the war, mainly in the Meuse-Argonne offensive, or at a rate of 20,000 a week. Had the war continued for two or three more years, it is predictable that the U.S. Army would have revised its infantry tactics--as did the French, British, and Germans by around 1916.

19. As an indicator to support this argument: In the major four naval actions between 1799 and 1803 (from the Battle of the Nile to Trafalgar) the British experienced a total of 4100 casualties. At Waterloo, British casualties were 7000; total allied casualties were 23,000. Wellington's command in that battle was 67,700 (this excludes the Prussian army which came onto the field late in the day), of which 24,000 were British. See Gaston Bodart, *Militär-historisches Kriegs-Lexikon (1618-1905)*, C. W. Stern, Vienna, 1908, passim.
20. This weapon was probably one of the first to be purposefully designed and developed in conformance to a set of prior ideas about what constituted an "optimum" system. The emphasis was on mobility, to support attacking infantry, and to be able to displace and set up business rapidly. It was a fine gun. However, its trajectory was too flat, and its round too light to be of maximum effectiveness for the subsequent trench warfare. A better all-around weapon was the German 105mm gun-howitzer which the U.S. Army shortly after World War I decided should be its preferred caliber. (The board of officers that deliberated on these issues was appropriately dubbed "The Caliber Board.") Some 15 years transpired during which the Ordnance Corps struggled to improve the German design, and some improvements were made. However, it was a close thing since the model year for the U.S. 105 was 1939.

21. A reviewer of an earlier version of this paper refers to this development as the "innovation of the recoilless guns..." and misinterpreted the discussion in such a way that we argue that it was growth in industrial capacity and ability to produce large quantities of munitions that permitted the innovation. Two points, one technical and one regarding the overall trend changes reflecting the interaction between tactical usage and industrialization, should be made. First, the weapon was *not* a recoilless gun; it was an artillery piece which necessarily recoils. Recoilless heavy caliber weapons did not appear until World War II. The latter, which employ a rocket principle for propulsion, differ markedly in tactical usage from artillery, a major reason being their prominent dust and flash signature which greatly endangers the gun crews by revealing their positions.

The notion that ability to produce large quantities of munitions led to the adoption of the long recoil artillery principle is entirely backwards with respect to the historical sequence. Neither the French, nor anyone else around the turn of the century, anticipated or expected to expend the large artillery tonnages that occurred in World War I. The '75 (as the previous footnote indicates) was "optimized" for mobility, and sized (along with ammunition chest) to a six-horse prime mover, which could move apace with infantry and cavalry and thereby preserve the army division concept.

- A more precise way of putting the historical sequence is as follows:

Without the long recoil principle, the large artillery expenditures of the Western Front, and the emergence of the new artillery tactics, would not have been possible. The "opportunity" for large-scale artillery usage arose from the breakdown of mobility and the ensuing static trench warfare. The latter was due to the high troop densities relative to the short frontal line from Switzerland to the sea. (On the Eastern front, World War I exhibited the classic 19th century emphasis upon maneuver--a point that appears to have been overlooked by many Western thinkers, the Germans excepted, of course.) The high troop densities were permitted by larger populations and an industrial capacity which made it possible to free relatively more manpower for military service, the point made in the text.

22. The purpose of this paragraph is to emphasize that industrialization (and its associated technical change and progress) has had unanticipated if not surprising effects on the military production function; but that the belief on the part of policy makers and force planners that there is some relationship between industrial and military capability has given support (or provided a rationale) to try to destroy or hamper an enemy's industrial capacity. All this, formally speaking, is an "argument" about the "production function," or, more loosely, an attempt to probe

the animal, and to advance the idea that the possibility of shifts in the function might create substitution elasticities that differ from what people might hope for or anticipate (the apparent intractability of casualties cited in Table 1 being our primary object of concern).

23. There are a number of ways to derive this factor. Our ratio is that in a theater army, a division slice of 45,000. Assume 5000-6000 in division maneuver battalions, 2500 division artillery, 800 in division combat engineers, and 600 in an armored cavalry squadron. Throw in another 2500 for corps' slice of artillery and combat engineers. The total is around 12,500.
24. The differentiation of combat from support personnel may seem offensive to some, since it can be argued that the support people play a necessary role and are part of the "team." This point is not denied. The critical question, however, centers around the allocation of manpower resources between the two broad categories and the support they *both* require in the over-all force structure.
25. For evidence to support this assertion, and the occurrence of which posed severe problems for the Army in World War II, see Robert Palmer et al., *The United States Army in World War II: The Army Ground Forces: The Procurement and Training of Ground Combat Troops* (Washington, D.C., Government Printing Office, 1948), pp. 14-28.

The condition in World War II was that the Navy and the Army Air Forces got a disproportionate share of the high-score (AGCT) inductees, and within the Army, the service forces got a disproportionate share of the rest. The combat ground forces got "the bottom of the barrel," which extended to noncommissioned officers. In October 1942, Lt. Gen. Leslie McNair commented, "We will pay dearly for this in battle." (See Table 1.)

One of the sobering thoughts about the increased capital intensity of our armed forces is that in combat, people from a lower intelligence percentile of our population are going against a higher percentile of the enemy's population. Whether "intelligence" is correlated with combat astuteness is an open question. It is our bet that it is. The contrary assumption is at best dangerous, for, if incorrect, it can partly account for our casualty experience. The assumption, of course, is highly compatible with elitist sentiments.

26. See, especially, D. Willard, *Lanchester as Force in History: An Analysis of Land Battles of the Years 1618-1905*, RAC-TP-74 (Bethesda, Md.: Research Analysis Corporation, November 1962). More recent studies are Herbert K. Weiss, "Combat Models and Historical Data: The U.S. Civil War," *Operations Research*, September-October 1966, pp. 759-790; and Martin J. Bailey, "Tactical and Lanchester Analysis of Combat in the U.S. Civil War," Draft MS dated December 4, 1970.

27. Determining what the relative productivities are, however difficult, is nevertheless worthy of effort.

28. A critic proposed an alternative to the Eq. (5) model which is

$$O_B = f(L, K, O_R)$$

where L and K are military labor and capital, and O_B and O_R are "output" of Blue and Red. One side's intelligence of the other's force structure and tactics then affects the marginal products of L and K. Although he felt our Eq. (5) was not "terribly illuminating," we find his alternative less so. Although it argues that intelligence has value (i.e., Blue's knowledge of O_R and vice versa), that argument seems to be its sole content; and, as such, it is not "terribly illuminating" either. One of the aspects of war is that tactics (and force structure) are often quickly modified as a result of operational experience, and casualties in particular. There is also the important subject of how one gets knowledge of tactical usage in peacetime, which is necessary to formulate coherent technical specifications for engineering development programs.

The ultimate test of the value of any model is probably its worth as an engine for empirical effort. If this criterion is accepted, then the variables must be susceptible to measurement, not just in "principle" but in terms of whatever real data may be around or what is capable of being generated by, say, field trials or operational testing. It is our contention that P's, at the appropriate lower levels of aggregation, can be empirically tackled. F's can be counted. A's can be inferred from casualty data.

At best, one side can only generate expectations about the other's "outputs." We are at a loss to imagine how this might be measured so as to test aspects of the critic's formulation.

29. All World War II bombardiers, to be qualified, had to achieve a minimum CEP of 230 feet from 12,000 feet bombing altitude. The average CEP was actually better. A six-aircraft flight, in two three-aircraft elements, of B-25s or B-26s could lay down a pattern of 24, 1000-pound bombs roughly 200 x 300, assuming a 50' bomb spacing between each of the four bombs per aircraft, and the second element flying about 100 feet behind the first. Each mission usually involved 4 to 6 flights. Yet bridges hit per mission was around .5. The number was also a sharply decreasing function of enemy flak intensity.

30. For a development of this point with respect to air-to-air combat, see Herbert K. Weiss, "Systems Analysis Problems of Limited War," *Annals of Reliability and Maintainability*, Vol. 5 (New York: AIAA, July 18, 1966). Weiss bases his argument on empirical examination of air-to-air combat records, which incidentally shows that individual kill scores of several hundred (as recorded by the Luftwaffe) are not unexpected. He also shows that a probability density function describing an ability to survive a "decisive combat" is U-shaped, suggesting that the concept of an "average" fighter is rare.

One potential and important implication of Weiss' hypothesis is that casualties experienced may be *in proportion* to force size. The larger force provides a higher target density which serves to reduce the target acquisition problem for the opponent's hawks. Weiss contends the Battle of Britain supports this particular model which, of course, refutes the Lanchester "N-square" and linear hypothesis. (Elsewhere, we advanced the idea that the casualty exchange rate in Indochina may not have been as high as press accounts suggest.)
31. Concern over these three shortcomings appears to be the major focus of most students of the weapons acquisition process, including the Rand effort of the past 15 or 20 years.
32. The automatic tank gun loader has been cited in Rand manpower project papers as an "example" of substituting capital for labor. This is a particularly sad (or good) example of the workings of the quest for "better" (or at least more costly) weapons. Actually, the automatic loader as a subsystem of the proposed Main Battle Tank arose from the twin "requirements" for rapid fire and reloading, and a lower profile that would reduce target size. However, the tank was conceived to launch the 152mm Shilellagh missile and its necessary associated caseless conventional ammunition. Caseless ammunition was seized upon to reduce weight by dispensing with a brass cartridge case. Even so, both the missile and the conventional round were probably too heavy to manhandle so as to facilitate rapid reloading and firing. Although no one really knows, these latter points may have been the real reason for the automatic loader. The manpower cost savings were subsequently seized upon to support the idea that a \$1.2 million per unit tank would be "cost-effective." Surely happier examples can be cited or at least imagined to illustrate the idea of substitution.

33. Even this understates the sorry condition. There are examples where good existing weapons are degraded by the workings of the acquisition system. The M-73 machine gun affixed to our otherwise very good tank is one example. Some of these tanks (M-60s) were later modified to employ the Shillelagh missiles/caseless ammunition system, the combat utility of which is doubtful. Even the AR 15 rifle (later dubbed the M-16) was degraded for combat use by a number of changes, one of which was an ammunition-propellant change that caused excessive malfunctions and which nearly undermined the troops' confidence in the weapon. These changes served to delay procurement in order to provide an increment of time to permit the "in-house" system to develop an exotic weapon of its own conception. Even the Air Force was obliged to scramble to affix a gun to the F-4 when air-to-air combat revealed that sole reliance on a heat-seeking missile was not sound. With some of these examples, it would have been possible to resolve much if not most of the uncertainty by operational testing. And with others, like the M-73 machine gun and the M-16, attention given to straightforward engineering tests would have averted the difficulty.
34. For a more detailed account of how that information failure is masked by extensive reliance on model building and computer simulations, which are fed by unvalidated empirical data, see my *Models, Data, and War: A Critique of the Study of Conventional Forces*, R-1526-PR (Santa Monica, Calif.: The Rand Corporation, March 1975). For an account of how we arrived at this condition, with an emphasis upon the macro-incentive structure, see my *Plowshares Into Swords: Managing the American Defense Establishment* (New York: Mason Lipscomb, 1973).
35. This implicitly assumes that an Army Brigade is "equivalent" to one Marine Regiment. However, an Army Brigade within a division is, strictly speaking, a headquarters unit, and, as such, possesses no administrative units like battalions. But since the typical U.S. Army division possesses from 9 to 11 battalions and three brigade headquarters, an "Army Brigade" within the division context can be reckoned as roughly equivalent to a Marine Corps Regiment.
- Normally, a Marine Corps Regiment is larger than the Army's equivalent of a three-battalion regiment, primarily because the Marine Corps has a larger rifle squad. However, by 1966, the Army began augmenting its infantry battalions with an additional rifle company. Hence, for most of the war, this augmented TO&E strength of an Army infantry battalion more closely approximated that of the Marine Corps.

36. Frank A. Reister, *Battle Casualties and Medical Statistics: U.S. Army Experience in the Korean War*, Surgeon General, Department of the Army, Washington, D.C., n.d., p. 130.
37. Reister, *ibid.*, *passim*. Wounded in action includes those who subsequently died of wounds, but excludes those wounded who were "carded for record only"--i.e., minor wounds. See Appendix B for a more detailed discussion of this subject.
38. However, the distinction between "killed in action" (KIA) and "died of wounds" (DOW) is not clear-cut. The criterion for KIA is a death that occurs before reaching a medical facility, to include a clearing station. The relative importance of these is critically related to evacuation capability (and policy) which, in turn, is affected by the type of operation. The rapid evacuation of wounded afforded by the helicopter has reduced the ratio of killed to total wounded, since it is well established that recovery is a sharply inverse function of the time between wounding and treatment at a well-staffed and -equipped facility. But it has also delivered to medical facilities many cases that cannot recover and, in past wars, would have died before reaching a medical facility. This latter effect, *ceteris paribus*, means fewer KIA and more DOW. The effect of rapid evacuation by helicopter, however, is to reduce the *overall* ratio of deaths to total deaths and wounded.
39. The following discussion draws extensively from Gilbert W. Beebe and Michael E. DeBakey, *Battle Casualties: Incidence, Mortality, and Logistic Considerations*, Charles C. Thomas, Springfield, Illinois, 1952; and Frank A. Reister, *Battle Casualties and Medical Statistics: U.S. Army Experience in the Korean War*, Surgeon General, Department of the Army, Washington, D.C., n.d., especially pp. 3-9. I am also indebted to Mr. Reister who, through conversation, provided helpful insights about the subject.
40. In the U.S. Army, the Medical Service has sole responsibility for reporting and records on disease and nonbattle injury (DNBI). In terms of overall incidence, this category exceeds battle casualties as a cause of manpower loss and medical work loads.
41. Here we use the distinction between "administrative" and "tactical" capability to refer to the important fact that some military units--like the company, brigade, and corps--are purely tactical entities; whereas others--like battalion, regiment, and division--are administrative entities although they may also exert tactical or operational control over the resources they own or which are assigned to them. The relevance of this distinction is that a purely tactical organization must look to some other entity for administrative "support," including personnel services such as food, supply, medical, and so on. An administrative entity, like a battalion or division, possesses its own medical and logistic capability, but it is expected to rely on outside and more specialized organizations for peak load or highly specialized service.

42. For a further discussion of this subject, see Beebe and DeBakey, op. cit., pp. 7-9.
43. Office of the Surgeon General, Patient Administration and Biostatistics Division, Release entitled "Statistical Data on Army Troops Wounded in Vietnam, January 1965-December 1972," 21 May 1973.
44. It should be pointed out that for World War II prior to January 1945, there were discrepancies between Adjutant General and Medical Service accounting of casualties which also varied as between Theaters. (In Europe, the discrepancy was only about two percent.) Up until January 1945, the Statistical Health Report, prepared by the Medical Service, contained some of the CRO cases, and this amount varied as between Theaters. After that date, both the Statistical Health Report and the Adjutant General's Report sought to adhere to the principle of the loss of at least one day from duty as a criterion. Reporting criteria for wounded (and killed due to hostile causes) were also changed during the course of the war to include cases incurred to and from combat missions, and were made explicit in an Army Regulation dated 10 December 1943. Hence frostbite cases experienced by air crewmen on combat missions were counted as wounded. Deaths from air crashes--landings, takeoffs, mid-air collisions in formation flying--incurred on combat missions were the major cause of Air Force KIAs reported *during* the war. For these and other reasons, World War II U.S. Army statistics on battle wounds should be gingerly employed in any attempt to make fine-grained comparisons as between Theaters.
45. Although we have not checked the TO&Es of medical units organic to Army versus Marine Corps Divisions, it is a good hypothesis that Marine Divisions possess less capacity for steady state medical capability. In amphibious operations, casualties occur in a surge as a consequence of the assault, and are accommodated by offshore ships. Army Divisions, on the other hand, have traditionally operated in a variety of diverse conditions and at a more steady state. Before the advent of the helicopter, a division might be required to operate in a setting where accessibility to rear-echelon medical facilities was difficult. Hence there was justification to endow Army Divisions with a greater organic medical service capability. These historical factors are likely to be reflected in present organizational structures.

46. This assertion, and ones like it, have been the object of much emotional controversy that has centered around weapon (especially small arms) design and even force structure issues. Only since the post-World War II period has some coherent research and testing been conducted to shed some evidence on the subject. Although much of that research has created additional controversy, some agreement has emerged that supports the above assertion.

Evidence supporting the assertion has been derived from the examination of 1173 cases in South Vietnam, where:

Causative Agent	Fatal	Non-Fatal	Ratio
Small arms	151	237	.64
Fragmenting	72	392	.18

See Joseph R. Blair, "Analyzing Data on Munitions Effectiveness and Wounds," *Army Management Views*, Vol. XV, p. 137.

47. This assertion depends, of course, on how heavy an armored vest is. In the range of 6-8 pounds, the weight most suitable for infantrymen, little protection is provided against high-velocity bullets (rifle and machine gun as contrasted with pistol). Moreover, upon striking and penetrating an armored vest a bullet will be induced to "tumble" much more quickly, thereby causing a larger wound track and hence a more serious wound.

GETTING THE MOST FROM PRECISION WEAPONS*

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Several years ago there was great excitement in the weapons analysis community about the new generation of precision weapons. The Thanh Hoa bridge was cut in two attacks with laser-guided bombs, where dozens of previous attacks with unguided bombs had failed. There were good reports on helicopter-mounted TOW from Vietnam, and the tests at Ansbach showed as high as 28 tanks killed per helicopter lost.

Then the first reports from the Middle East war of 1973 came in, indicating that the Arabs had made very effective use of Grail anti-aircraft missiles and Sagger antitank missiles, and the Israelis of Maverick. Ian Smart, Deputy Director of the Royal Institute of International Affairs (London), compared the change on the battlefield to the advent of the English longbow at the Battle of Crécy in the 14th century. He told a BBC audience:

Soviet technology in Arab hands has consigned
to history [an era in which] the tank and
aircraft ruled the battlefield.

However, it was not long before amendatory reports began to come in. Additional tests showed that the tanks per helicopter figure in the Ansbach tests was probably too high for realistic conditions in full-scale combat. Analysis of Israeli data and later reports of the officers engaged showed that many Israeli tank losses were due to unguided RPG-7 rocket grenades, to the sheer numbers of Sagers launched, and to the early absence of combined arms support. The Grails were a problem, but not as decisive as the Arab use of a Soviet-style interlocking network of antiair weapons. Then, in 1974 and 1975, exercises in Europe showed that NATO forces would not have benefited greatly from *on-hand* precision-guided munitions, given both the types deployed and the stocks on hand, and given existing tactics.

* The views expressed in this paper are the author's own, and are not necessarily shared by Rand or its research sponsors.

Thus the revolution has not yet arrived. The approach of this paper is to enumerate some of the *potential* values of precision weapons, to say something of the current status with respect to obtaining each value, and to generate discussion on the technical and institutional barriers that must be dealt with if the full potential is to be reached.¹ In general, to the extent we know about them, the barriers on the Soviet side are quite different from those on our side, and, on the whole, appear less severe.

I shall now discuss eight important potential values which may be obtained (by either side) by suitably exploiting precision-guided munitions (PGMs) and remotely piloted vehicles (RPVs). In each case I first make a statement about the potential value and then discuss the current status of the problems in obtaining that value and the prospects for the United States and the Soviet Union in that regard. (These values have been discussed in various Rand studies over the past few years, and my paper *Precision-Guided Weapons*² gives a more detailed rationale for their relevance.)

POTENTIAL VALUE 1: GREATER CAPABILITIES

Many PGMs and RPVs appear to represent a quantum jump in capabilities even when compared to more expensive traditional weapons systems.

At their best, PGMs and RPVs can result in improvements in the probability of killing targets on the order of 10 to 100 times. A pilot on the ground can accurately control a remotely piloted vehicle flying hundreds of miles away. These systems can be launched from a variety of platforms and potentially may result in a major shift in the kinds of weapons used on both sides, as well as in the vulnerability of traditional systems.

On the other hand, many of the current systems cannot be used at night, against targets shielded by smoke or haze, during bad weather, or against suitably camouflaged targets. There are already available a number of countermeasures which will reduce their effectiveness and each year is likely to bring others. Their crews are not well protected in many cases, and the effectiveness of the weapons systems can be cut tactically by attacking these crews.

Many of these problems can be solved, particularly for the one-on-one case. For example, long-wave infrared (LWIR) systems will permit guidance at night and in certain types of bad weather. Crews can be protected and standoff ranges increased.

At present it appears that the United States may have some edge in exploiting nonvisual guidance systems such as LWIR. On the other hand, the Soviets seem to be exploiting the ground-based versions of visual-guidance systems the most. They have produced large quantities of antitank PGMs and mounted them on armored vehicles, with some protection for the crews. They have built surface-to-surface cruise missiles for some years, though many seemed to have rather primitive terminal guidance. So far, Soviet technical progress in air-to-surface PGMs seems much less than our own.

In many respects the prospects for the Soviets to exploit PGMs seem quite good: their military procurement tendency is to have large numbers of vehicles, something which fits well with exploiting PGMs. They have fewer service-centered institutional barriers which inhibit the use of land-based and air-force-launched PGMs against naval vessels, etc. They have a predilection for planning combined arms operations, which, again, helps them to exploit PGMs and RPVs. By contrast, service leadership in the United States still puts greatest emphasis on procuring new versions of traditional systems. More will be said on this as I discuss the next potential value. But a most important point is that even if the U.S. achieves desired qualitative goals, it needs greater quantities of these weapons, especially of antitank weapons.

POTENTIAL VALUE 2: SMALL CONCEALABLE UNITS

PGMs might be best employed in small units which are concealable and which do not risk too much value in one place. Such units can still be very powerful.

In many respects, U.S. policy currently runs in the wrong direction to realize this potential. For land forces, the Army calls for development emphasis on the Big Five,³ all large expensive systems, each with multiple functions. We do not have the equivalent of the Soviets' Sagger mounted

on various vehicles. Our Air Force has put high priority on large, multipurpose penetrating aircraft, as well as the AWACS airborne warning system that concentrates great value in a single airplane. Our Navy is asking for very large nuclear-powered aircraft carriers and for nuclear-powered strike cruisers, and there is little emphasis on exploiting cruise missiles from conventionally powered frigates--which, in any case, would require exemption from the Congressional mandate to use nuclear power. The Soviets, on the other hand, have the Nanuchka-class corvette and have loaded their larger vessels with numerous missiles. They are exploiting new vertical takeoff aircraft technologies as well as PGMs by putting them on medium-size platforms.

A problem with going to the small-unit structure is keeping track of where each unit is and making them operate in a mutually supportive and coordinated way. (See the discussion of supporting structure, below.) It is too early to tell which side will fully implement the small units strategy in a coordinated way. The Soviets will probably have a good head start based on the practical experience of possessing large numbers of small vehicles during the 1970s, while it appears that the United States will be inhibited by both service tradition and Congressional mandate (in the case of naval vessels) from exploiting this potential until the 1980s.

POTENTIAL VALUE 3: USING MISSILES FOR THE OFFENSE

The offense (tactically speaking) will profit from future longer-range PGMs; it will also require the development of new tactics.⁴

The sea-launched cruise missile (SLCM) and other cruise missiles can be put to good use offensively, but the U.S. is not adequately complementing this capability with a suitable reconnaissance capability--either by RPV or satellite. (The Soviets, on the other hand, have a relatively advanced ocean surveillance system.) With respect to land-battle tactics, the United States has not yet developed much in the way of offensive tactics which would capitalize on PGMs. The Soviets are probably doing more in this regard through their emphasis on the PGM-equipped BRDM-2 and BMD

mechanized fighting vehicles. On the other hand, Soviet technical progress on long-range guidance systems for PGMs aimed at fixed targets seems far behind progress in the United States.

It might be said in summary that the U.S. is generally ahead in the technology for weapons suitable to the offense as demonstrated on the proving ground but has not yet deployed very many such missiles, and has not developed and practiced suitable tactics. Soviet progress on tactics for offensive use of PGMs is a bit unclear at this stage; on the other hand, they seem to have made more progress than the U.S. in using a total combined-arms approach for offensive purposes.

POTENTIAL VALUE 4: LATERAL MOVEMENT

PGMs can be moved quickly laterally along a front and they can have great military effectiveness per ton of weight. NATO's front thus does not have to be defended only with weapons in place, an important matter in view of current maldeployments. To the extent that PGMs can make forces smaller and lighter per unit of military effectiveness, this permits weapons (some of which can be vehicle-mounted) to be moved more readily and placed where the action is.⁵ A second opportunity is to send reinforcements from the U.S. to the places where they are most needed, not just to back up presently deployed U.S. forces.

On the U.S. side little has been done with respect to land warfare plans and tactics for lateral deployment or for the earmarking of transport. Neither are adequate command-control networks yet available on the NATO side. But there does appear to be progress. Two years ago, analysts were sometimes warned by American political authorities not to even mention the U.S. reinforcement of non-U.S. NATO forces. Now, however, these matters are formally treated in NATO plans for Brigades 75 and 76. But while some progress is being made in planning, there is still a minimum of actual physical support, and, except for the seldom-praised M551, the U.S. has no well-developed lightweight vehicle on which to mount U.S. antitank guided missiles.

On the Soviet side there is likely to be less of a problem with the command-control network. If the combat situation is Soviet-initiated, the problem of where to send additional PGM forces may be handled by the Soviets' usual method of following up success with more forces while writing off failed thrusts.

POTENTIAL VALUE 5: EFFICIENCY THROUGH CENTRALIZATION

PGMs and RPVs may permit a greater centralization of forces, basing them, for example, in the United States, then dispatching them for combat use. This centralization might be more in concept, and may not necessarily be in terms of where they are deployed geographically, but involve pulling forces from wherever they are needed less to wherever they are needed more. Such centralization is increasingly necessary for the U.S. as forward bases are lost or become dubious. Earmarked forward forces may be a luxury which the U.S. can no longer afford.

While the U.S. has much more experience with the mechanics of fast overseas projection of force than the Soviet Union, Soviet capabilities are improving rapidly. The U.S. would usually have some problems of compatibility with indigenous forces which the Soviets might not have. Moreover, one must ask if the American JCS system is adequate for making full use of centrally based U.S. forces. One must also ask how well the U.S. services would work together in a combined-arms expeditionary task force. As to geography, the Soviet Union is better placed for many likely contingencies.

For the armies and air forces on both sides, resupply is likely to be a crucial factor. Both navies have a fair amount of built-in replenishment capability, but the U.S. Navy is probably ahead. A relatively unexplored possibility is the extent to which the U.S. Navy can support the other services with forward-deployed maintenance and communication facilities.

Being able to use all of its assets is absolutely essential to the United States in any confrontation with the Soviets. At the present we are probably quite far from having a suitably coordinated plan under which all three Services would work together in a deployed mobile force. But we

do have one advantage over the Soviets: the U.S. has superior data processing systems that would help keep track of reserve and deployed forces, and which would facilitate their control. That is an advantage which the U.S. must exploit to the fullest.

POTENTIAL VALUE 6: AVOIDING ORGANIZATIONAL STODGINESS

The new weapons are largely indifferent to what kind of platform carries them to the point of launch. They will probably work best if tables of organization and equipment (TO&E's) are revamped to exploit them. Among other things, this suggests that roles and missions may become blurred and that traditional service assignments should be changed to get a task done.

So far TO&E's on the U.S. side have not changed to any substantial degree. The Soviets, however, have made a major change in the emphasis given, and now include BMPs--some of which are missile-armed--in their most modern operational units. Moreover, they have emphasized combined-arms operations; the extension from those tactics to make full tactical use of PGMs is not a very big step. On the other hand, the Soviet practice of following norms and a relatively inflexible adherence to standing orders as well as field orders, runs counter to the need in the PGM era for having and using current battle information on a large number of independently moving small units. U.S. land forces have not done much tactical or doctrinal development along these lines either, but they have long followed a doctrine which gives substantial independence within broad guidelines to junior commanders.

POTENTIAL VALUE 7: COST SAVINGS

PGMs and RPVs can be cheap to produce and cheap to maintain for a given level of effectiveness.

Currently, some PGMs are cheap and simple (like TOW, Pave Way, and Sagger) and some are not (like Condor). It is beyond the scope of this paper to explore fully why some of the longer range missiles are currently

so expensive and so complex. One factor, almost certainly, is that these systems tend to follow the long standing practices of the aerospace industry and its government monitors of building high-reliability devices because the safety of human pilots depends on those devices. A second factor, for the U.S., may be an excessive use of redundant features to counter jamming, where the production of sheer numbers, which is the Soviet tendency, might, in fact, be a more cost-effective solution. For the present, though, these are merely speculations, and not the results of analysis.

POTENTIAL VALUE 8: SAVINGS WHEN MODERNIZING

Weapon systems can increasingly be designed independently of platforms. This will permit each to obsolesce independently of the other, with consequent savings. For example, a basic cruise missile vehicle might have a life of 20 years; its payload modules might be changed several times in that period.

Currently most funds for U.S. air and land weapons are going into large penetrating vehicles with tightly integrated weapons systems. Modularity has been a goal of design engineers for many years, but it is treated more in theory than in practical designs for production. Still there are a number of examples on the commercial side, where ARINC specifications have resulted in a highly practical design for commercial aviation electronic systems. But in the military, some influential person always wants to use that last 300 cubic inches of space. Initial performance specifications usually dominate over designs that might be efficient over a ten-year period. There is no evidence which I have seen that the Soviets do any better. But it is worth noting that many features of modern technology--on which the U.S. has a current lead in terms of production capability--facilitate modular design: weights are going down, volumes are going down, power requirements and heat dissipation needs are decreasing, and new microcircuitry can help make interfaces take less space and cost less.

THE IMPORTANCE OF A SUPPORTING STRUCTURE

For both Americans and Soviets to get the most out of PGMs, they will need a supporting structure:

- (a) pioneer reconnaissance to localize targets,
- (b) target acquisition and designation,
- (c) a command function to allocate and marshal weapons and to authorize release,
- (d) a combined arms partnership which protects PGM crews and designator teams while they do their job,
- (e) lateral battle area transport, and
- (f) a network to replenish expended weapons stocks.

A number of aspects of the supporting structures were treated above, but here I place them all together. It is important to note that even a weapon with a kill probability approaching 1.0 cannot be used effectively unless it is aimed at a suitable acquired target, and the task of efficiently associating 500 targets with 1000 missiles can be a substantial one. Fortunately, many of the tasks noted above are things which the United States knows how to do well; the problem is that tactics and communications backup for many of them are not yet even as far as the planning stage. As noted under Potential Value 5, the efficient performance of many of these tasks can be helped by advanced data processing devices, a technological field in which the U.S. has some advantage over the Soviet Union.

By the same token, an equally crucial aspect of battle will be the destruction of the enemy's supporting structure for his own PGMs.

So far not very much has been done by U.S. forces to prepare to capitalize on vulnerabilities in Warsaw Pact PGM supporting structures. There are two activities, though, which may lead the way toward effective plans. First, the work of the team led by Major General Jasper Welch on Soviet patterns of operation points the way toward capitalizing on their tendency to have inflexible plans. The destruction of forces needed to meet artillery

barrage norms may cause a movement to be cancelled, for example. Second, the debate over the vulnerability of the airborne warning and control system (AWACS) is a case in point, and its answers may be generalized.

Nonetheless, on our side, not much thinking has been done about the design of the supporting structure. Nor is there much evidence that the Soviets have thought about it in the terms set forth in (a) through (f) above.

POTENTIAL POLITICAL ADVANTAGES AND PROBLEMS

This paper concludes by noting that the full exploitation of precision weapons can interact with the design of appropriate political policies, some of which, in turn, will require the development of matching military tactics. Perhaps the most important point is that precision weapons permit precision in the physical damage done, and thus permit more precise political handling of emerging crises so that the military actions can conform more exactly to political purposes. There can be a better chance of securing an objective without escalation due to misinterpretation of the military signals which convey an adversary's intent. I have already noted that the new weapons can be moved about more easily, and this in turn calls for appropriate political preparations both with the government from whose territory they might be moved and with the government into whose territory they must be received for the military job at hand. Finally, there is the prospect for nonnuclear weapons to head off desires on the part of some powers who now covet nuclear weapons, since nonnuclear weapons may do the same job. This may help in slowing nuclear spread.

There are also some problems which must be foreseen. The small size and potential for concealment of modern PGMs are making "national means of verification" a weak reed, and this must be recognized at the political level if arms control negotiations are to be meaningful. In arms control negotiations, as in many other aspects of military discussions, it will have to be recognized that the new weapons are blurring the distinction

between "strategic" and "tactical" forces as well as between "forward-based systems" and home-based forces. It is also a major political factor that the new weapons are facilitating a dispersal of military power, and small states can increasingly dispose of powerful forces. This last factor is evidenced by the current and massive wave of arms transfers, some to unstable regimes. There are already multiple sellers of modern weapons and multiple buyers, and there is an increasing prospect that there will be third-world producers of very powerful and efficient weapons.

I have mentioned enough potential changes--many of them of great importance to the two superpowers--to indicate that military strategy and tactics may be in for some major revisions. Not this year. Things are not moving that fast on either side. But many of these shifts are coming in the lifetime of the posture we are now laying down. Exploiting our advantages is necessary; otherwise, this is a competition we are losing in terms of raw numbers. And the reason for this Workshop is to chart a course for exploiting these and other technologies.

GETTING THE MOST FROM PRECISION WEAPONS

Endnotes

1. By institutional barriers I mean those like the separation of service procurement responsibility from combat responsibility, the tradition that naval threats must be dealt with by naval forces, and so on.
2. Adelphi Paper No. 118, The International Institute for Strategic Studies, London, Summer 1975.
3. The XM-1 tank, MICV armored fighting vehicle, AAH armed attack helicopter, UTTAS utility helicopter, and SAM-D air defense system.
4. This brief treatment greatly oversimplifies a highly complex topic, since theater-wide offensive thrusts need good defenses in most sectors, and the campaign on both sides involves attempts at movements and countermovements.
5. The Soviets have several PGM-equipped armored vehicles lighter than our M551 and have bigger helicopters.

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WORKSHOP ON ASYMMETRIES IN EXPLOITING TECHNOLOGY AS RELATED TO
THE U. S. - SOVIET COMPETITION: UNCLASSIFIED SUPPORTING PAPERS

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