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Specific individual military transformations achieve full significance only in the context of the broader processes of multiple interrelated transformations taking place in competition with those of one or more opponents. This study examines one historical case of broad systemic competitive processes to clarify the underlying dynamics: Japan and the United States between the two world wars. The armed forces of both nations envisioned significant risk of war between them and sought, with varying focus and vigor, to prepare. These efforts are contrasted in operational concept, doctrine, and technology. Japanese forces achieved a very high level of excellence in tactical execution, a level that American forces did not initially match in many areas. Moreover, Japan entered the war with matériel that was in many areas equal if not superior to that of the U.S. in both quantity and quality. But the effort the U.S. had put into capabilities for planning and executing higher-level operations frequently enabled its forces to pit strength against weakness, resulting in far faster erosion of Japan's defenses than the Japanese had anticipated. Thus American transformation efforts brought advantages beyond those of simple weight of forces.

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Summary

This section provides a brief summary of the principal facts and arguments of this report which are presented in more detail and documented in the sections that follow.[1]

Purpose and focus

Historical studies have been a major source of insight into the processes of military transformation. In most instances they have begun by selecting a specific instance of transformation which could be identified as significant on the basis of subsequent history and then tracing its origins and trajectory. Such studies have been valuable in revealing the inner workings of transformation processes. They have been less useful in understanding the broader processes by which military institutions conceive, embrace, or reject transformative opportunities. These operate in an environment of multiple uncertainties and competing priorities and can best be understood from a system-wide ex ante perspective. This study is a brief exploration of such an approach. It is not comprehensive or definitive and indeed I note several important issues left open at its conclusion.

The case examined is that of Japan and the United States in the period between the two world wars.[2] This offers the practical advan-

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[1] While the responsibility for this paper and its conclusions rests entirely with me, I must acknowledge the many people who have given very substantial help. First is Andrew W. Marshall who, as Director of Net Assessment in the Office of the Secretary of Defense, not only sponsored the study but also provided very valuable comment and guidance. The extended comments of Edward J. Drea, Charles R. Haberlein, Thomas C. Hone, Wayne P. Hughes, Jr., and Mark R. Peattie have all had very positive effects on my thinking and the clarity and accuracy of my writing. Many other colleagues and friends also have made important contributions.

tages of reasonably good documentation as well as clarity of focus stemming from the fact that the two nations identified one another as especially prominent among prospective opponents throughout the period in question.

Relevance to today

Beyond this, the case of Japan is particularly pertinent to some of the problems the U.S. might have to face in the 21st century. Japan was the first of non-Western nations to make a sustained and concerted effort to match Western states in power and wealth. A number of other nations are following the path that Japan pioneered, and it is possible that we might come into conflict with one or another of them, as we did with Japan.

In setting out to gain wealth and power for their nation, Japan's leaders grasped the need to recast their society and polity, at least in large measure, in the European mold. Farsighted though they were, it is scarcely surprising that they did not fully recognize the implications of this daring and unprecedented societal transformation. Fearing that too precipitous a plunge into modernity could undermine the very bases of their society they sought to erect stabilizing levees to hold back the deluge, the military services chief among them. Tragically and ironically, it was the very attempt by the Japanese armed services to preserve and uphold the power entrusted to them in an effort to ensure stability that did so much to propel Japan into a desperate war that ultimately brought it into conflict with every remaining great power on Earth.

No nation will ever follow exactly the path of Japan, but it is not inconceivable that the strains inherent in rapid modernization will

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[2] In discussing this case I address it as if the war that followed was a two-sided duel involving only the United States and Japan. While this simplification serves rhetorical as well as analytical convenience, the reader is cautioned to bear in mind that it embodies a significant historical distortion in that a number of other nations played major roles in the war itself – most prominently China, Britain, and Australia.

lead others to senseless conflicts. Our first and best defense is to recognize and forestall the processes that are leading others toward war with us. As there can be no guarantee that we will succeed in other cases better than our leaders did with Japan in the period before World War II, however, we must also be ready to defend ourselves by force if need be. That of course is the focus of this report.

National comparisons

Japan gained great industrial, technological, and military capacity with remarkable speed. Emerging from a quasi-feudal state only in the 1860s, by the 1930s it had military forces that ranked with the world's best, technology resources equal in quality if not quantity to those of many advanced European nations, and the ability to produce at least limited quantities of all kinds of modern military matériel.

More precise measurements of relative economic potential involve difficulties relating to the great difference in structure between the economy of Japan and that of the U.S. in 1930s. Measured at market rates of exchange America's economy was roughly seven times as large. This is a good indicator of potential to produce modern military hardware, as is suggested also by the fact that U.S. peacetime output of many kinds of modern industrial goods was five to ten times as great as Japan's.[3]

Given these disparities it is remarkable that for most of the interwar period the resources Japan put into defense were roughly equivalent to those of the U.S. In part it was able to do this because so much of military input, particularly in those days, is manpower. As is characteristic of modernizing economies generally, manpower in Japan was far less expensive, relative to industrial goods, than in the U.S. This disparity was by no means restricted to manpower defi-

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[3] These and other economic comparisons are detailed in William D. O'Neil, *Interwar U.S. and Japanese National Product and Defense Expenditure*, CIM D0007249.A1, Alexandria, Virginia: CNA Corporation, Jun 2003.

cient in skills or quality; even highly qualified scientists and engineers could be employed far more cheaply (measured in these terms) than in the United States. Thus, with the United States devoting a relatively modest portion of its national product to defense, it was possible for Japan to roughly match American defense resources without placing an intolerable burden on its economy.

Of course this in one way reduces the present relevance of the comparison between the circumstances of today with those of the interwar period. Had the U.S. then devoted a proportion of its national product to defense equivalent to that during the Cold War, or even that of today, Japan would have found, like the Soviet Union, that it could match American defense resources only at the cost of severely eroding its economic viability. At the same time, however, the rough equivalence of resources for defense sharpens the comparison of transformations.

The armed forces

Japan's forces

In their appointed roles as pillars of the Japanese state the nation's army and navy exercised great political power, both constitutional and extra-constitutional. Each had its own views of Japan's defense needs and priorities. The army saw the country's destiny on the Asian Continent and was wary of Russia as chief rival for control of the land and resources of Northeast Asia. To the navy, the large U.S. fleet presented the greatest threat to Japan's well-being and independence of action. Rivals for national power, the two services bickered much and cooperated little.

Each sought to adapt its forces and doctrine to its understanding of Japan's needs and resources. The army believed that it needed to stand ready to defeat Russian forces in Asia so decisively as to forestall their reinforcement and resupply from the great resources of European Russia. It had accomplished this once, against the Czarist régime in 1904-5. This had been a desperate struggle that had all

but exhausted Japan's resources before Russia finally gave in and army leaders believed that it was only superior Japanese determination and valor, together with excellence in battle tactics, that had enabled them to carry the day against their larger adversary.

Japan's navy too had played an important part. The Russian fleet had in principle been the stronger and could have cut off Japan's forces on the continent had the navy not defeated it in repeated engagements, including the climactic Battle of Tsushima. The navy was very concerned about the United States because of the strength and relative proximity of America's fleet. Some senior officers believed that it was futile to try to compete with so large and rich a nation and instead counseled a course of accommodation; they led IJN acceptance of Washington's proposals for naval arms limitation in 1922 and 1930. To others, the inferior position of Japan in the arms treaties – it was allowed only the world's third-largest fleet, behind the U.S. and Britain – was both a threat to the nation's security and a humiliating affront to its sovereign dignity. In the 1930s these hard-line nationalists gained firm control over the navy, determined to bring it to a position of full equality with the U.S.

In looking back on the Russo-Japanese War both services took from itthe lesson that they must compensate for Japan's material deficiencies through superiority in spirit and tactical execution. The navy, in addition, was led to conclude that its matériel must be of superior quality if not quantity, and closely suited to its tactical concepts. Because Japan's involvement in World War I was not deep, the Russo-Japanese War remained formative for the nation's military concepts and doctrines.

America's forces

The U.S. Army had a background and outlook that differed vastly from that of its counterpart across the Pacific. Its officers had grown up in a tiny force that was largely devoted to guarding frontiers against irregular forces of various sorts. They had been educated on the army's experience of enormous mobilization and intense conflict fought over great distances in the American Civil War. And they

had experienced much the same themselves in the 19 months of America's involvement in the First World War. From this they distilled a rather odd amalgam of faith in the power of the individual rifleman, supported by artillery, to fight a mobile, "open" war together with an appreciation of the operational and logistical challenges of fighting great wars over great distances. Very much in a subordinate position in America's political structure, the army had no national strategic concept of its own. It laid plans for possible wars with various contenders, including Japan, but they lacked any political intent or context.

The U.S. Navy, like its Japanese counterpart, had all but been created anew at the end of the 19th century, and by 1920 little but nostalgic memories of the tradition of the old sailing navy remained. Responding, like the Japanese Navy, to the sea-power theories of America's own Alfred T. Mahan, the U.S. Navy conceived its mission in terms of defeating the enemy's battle fleet in order to gain freedom of action at sea and deny sea routes to its foes. In World War I it had found itself in fact almost entirely committed to the fight against the German submarine threat, but this experience had made only modest impress on its doctrinal views. In a mirror-image of Japanese naval views, the U.S. Navy focused on Japan as having the largest and closest fleet, and counseled that the U.S. must be prepared to defend its interests in the Western Pacific, including its colony of the Philippines.

As military planning proceeded, it became clear that prospects were bleak for the army being able to hold the Philippines for long enough for the navy to get there to relieve them. The U.S. had no secure bases west of Hawaii, and even that was vulnerable. It would probably have taken at least 75,000 troops to adequately secure the main Philippine island of Luzon against a strong Japanese landing – more than five times as many as the U.S. maintained there. Japan held most of the islands between Hawaii and the Philippines, so bases would have to be seized and put in operation before the fleet could reach the Western Pacific and confront Japan. Thus the U.S. Navy accepted that the Philippines must be sacrificed initially. The navy would force its way across the Pacific in an extended naval and

amphibious campaign, land the army to re-take the Philippines, meet and defeat the Japanese fleet in a climactic battle (or bottle it up in its ports), and blockade Japan until it submitted. The army, seeing no alternative, glumly went along.

The U.S. differed structurally from Japan in having two semi-independent services as auxiliaries to the principal services. The U.S. Marine Corps, not yet the legally separate service it became in 1947, was tied to the Navy. The Army Air Corps, which became the Army Air Forces before finally gaining full independence, was at least partially within the Army's orbit. The marines worked to develop an amphibious assault capability so as to seize and defend the bases that were the key to the planned Transpacific offensive. The army's airmen had wider visions – independent strategic bombardment operations that would destroy critical nodes of the enemy's web of essential industry in the first days or weeks of a war, thus crippling the foe and offering him no alternative but to yield.

Paths of transformation

None of this would have mattered greatly, of course, had not political events led to war. War between the two nations was certainly not foreordained. But nevertheless it came. While Japan determined the details of its timing and chose them to its best advantage, neither side could know when or whether the trial of arms would come during the long period of preparation. They were left to prepare themselves as best they could, among all the uncertainties they faced.

The navies

The two navies had strikingly symmetric expectations of a great sea battle in the Western Pacific. The principal difference was that the Americans had to concern themselves with the process by which they would get there, while the Japanese could rest assured that the U.S. fleet must come to them in order to pose a threat. Naval men of both nations generally regarded the battleship as the arbiter of sea power, but were keenly interested in the new airplanes, subma-

rines, and, in the U.S., airships. With construction of new battleships blocked by the naval treaties, they were all the more motivated to look to the air and depths for alternative modes of striking power. Both pushed ahead with development of these new vehicles, and Japan also was very active in building the cruisers and destroyers that the treaties did allow them. Moreover, Japan was much more vigorous in its efforts to upgrade its older battleships, although the U.S. Navy did press hard to improve its long-range battleship gunnery. In general the Japanese, hyper-conscious of their treaty-enforced inferiority in battleship forces, pursued a variety of techniques intended to wear down the strength of the opposing fleet before the final confrontation. These included submarines, land-based naval strike aircraft, night torpedo attacks by smaller surface ships, and long-range daylight torpedo attacks.

It might seem from this that the Imperial Japanese Navy (IJN) pursued more transformation options than did the U.S. In a way that is so. The Japanese had a very definite tactical concept and focused intense efforts on means to implement it. The U.S. Navy (USN) had some clear tactical views as well, but did not focus so intently on them. On the other hand, the somewhat looser American approach left more room for other paths, such as radar and cryptography. There was no technological reason why Japan could not have developed radar and advanced cryptographic capabilities on the same timescale as America, but these did not fit into the IJN's scheme of things. Of course radar would have been very valuable to their navy, and so would more secure communications. But they were ideas not likely to occur to general line naval officers, and the specialists who might have spawned them were kept on a short leash.

Both navies sought feedback on their transformation programs through equipment tests, wargaming, analysis of exercises and operational experience, and deliberate operational experimentation. They gained a great deal from this, but not as much as they might have. Both concentrated on proving and refining their concepts, largely to the exclusion of challenging them. Because of this, the challenges of war brought more painful surprises than they might

have. And neither took much advantage of the potential of scientific analysis of operational concepts.

The USN enjoyed a major structural advantage in transformation: the strength of American industry. The navy of course had not created this advantage, but it was well aware of it and sought both to foster and exploit it. This facilitated many technological and even operational transformation efforts of real significance. The Japanese services had greater powers of command over their nation's industry, but this was not adequate compensation for its weaknesses at best, and often enough backfired. Another American advantage – or perhaps it would be more correct to see it as a Japanese disadvantage – lay in cooperation between the services. In the United States it was far less than ideal, but not virtually nonexistent. In Japan the army and navy seemed all but absolutely determined to go separate ways.

The armies

The two armies did not focus specifically on each other. While each acknowledged in principle that the other was a major possible opponent, Japan's army concentrated most of its energy on nearby Russia while in the U.S. a major concern seems to have been with possible invasion of America by a foreign power!

In the early 1920s the U.S. Army transformed itself greatly from what it had been before the First World War, but this tended somewhat to stifle further transformation. In terms of tactical doctrine and equipment the army changed relatively little up to 1940, when the shock of France's swift defeat stimulated a massive effort still underway at the time of Pearl Harbor.

The great exception to this pattern was the development of the air arm. Indeed, virtually all of the resources beyond those needed simply to maintain force levels went to the Air Corps. In the 1930s airplane performance was improving very rapidly – much more so than before. There was a heady sense of boundless potential. Having concluded that the future lay with strategic bombing, the Air

Corps pushed to develop formidable heavy bombers and the doctrine for their employment. Slighter emphasis was placed on fighters and lighter bombers.

Like the navy, the army had some room for decentralized initiative. It too developed radar and cryptology. At the Field Artillery School enterprising officers developed means for coordinating and concentrating fires to an unprecedented degree. Also like the navy, the army drew on U.S. industry in areas like transportation, engineer equipment, and radio.

Lacking the U.S. Army's huge stock of weapons and other matériel from World War I, the Imperial Japanese Army (IJA) devoted somewhat more effort to developing and procuring these items. It also developed tanks and put them into production, as its American counterpart largely did not. Because it intended to operate on the Asian Continent, the IJA developed a capability for amphibious operations (but not direct assault on defended shores) with specialized ships and craft to support it.

Japan's army put much effort into developing its own air forces. Its dominant concern in the 1930s was to achieve air superiority over the battle area, with bombing forces to exploit this by attacking enemy rear areas. In tandem (but competition) with the IJN, it worked to build the nation's aircraft industry.

Two very important areas of transformation are less obvious because they involved fewer physical manifestations of equipment development and acquisition.

The quiet transformations

Fighting spirit has always been very important in war and cultivated by successful fighting organizations, including the U.S. services. World War I had sounded a strong cautionary note about expecting too much of it, but it was an experience that Japan did not share. Knowing Japan's weakness in material terms, the IJA and IJN set out to strengthen their fighting spirit, and did so with remarkable effectiveness. Their enemies were amazed by the fortitude and determi-

nation displayed by Japanese forces throughout the war. Even when the matériel of those forces had very largely been destroyed or neutralized, even when the personnel were severely wanting in individual and unit training, their fighting spirit remained almost undimmed and continued to make them dangerous when closely engaged.

The other major quiet transformation was in operational movement and logistics. The American services had gained unique experience in operating very far from home and bases, most recently during the First World War in Europe, and sought to master the operational complexities of long-distance warfare. The Japanese, lacking this experience and feeling that such abstract concerns tended to conflict with their drive for offensive spirit, largely neglected them.

In the Pacific War's early stages, Japanese operational planners depended heavily on brilliant and daring tactical execution and, with few and limited exceptions, were not disappointed. Within a few months Japan occupied vast regions of Southeast Asia and the Southwest Pacific, in addition to securing its hold on the islands of the Central Pacific. It was left with forces at least equal in number and often superior in fighting quality to those that remained to the U.S. and its scattered allies in the region.

The operational capabilities of American forces – their ability to plan, execute, and support large-scale coordinated operations over great distances – enabled them to counterattack with a speed and force not anticipated by the Japanese. The Pacific, with its vast spaces and limited forces on either side, was the ideal stage for employment of these operational abilities. Even though individual American fighting units often were not up to the best Japanese standards of tactical effectiveness, and despite that lack of any general material superiority at this stage of the war, the U.S. was able consistently to pit operational strength against Japanese weakness in ways that severely eroded Japan's forces and chipped away at their strategic position.

It is often said that America's industrial might was overwhelming and that Japan's resistance was crushed by the sheer weight of it.

This is true to an extent, but it is far from the whole story. In fact, the U.S. gained the upper hand well before its industrial strength came into real play in the Pacific.

Deficiencies and lessons

Thus on the whole, American transformation can reasonably be said to have succeeded better than Japan's. But both had serious deficiencies from which we can learn much.

I have already alluded to the tendency in both nations to seek confirmation and refinement of existing concepts and to avert their gaze from other possibilities. In Japan this went so far as to threaten assassination of officers who pressed heterodox views.[4] In the U.S., without so extreme an emphasis on aggressive spirit, those who questioned orthodoxy too sharply were merely forced into retirement, but the overall effect was not greatly different. In each nation, the services failed to find many weaknesses and opportunities that could readily have been revealed simply because they did not choose to look. On the whole the Americans seem to have been more ready to accept conflicting evidence, and gained from doing so. The difference was not vast, but it was very important.

A complementary finding is that the somewhat less structured approach in the United States seemed overall to produce more robust transformation. The Japanese services had very clearly articulated doctrinal concepts and were very serious about improving their ability to execute them, with results that often were very impressive. But in the U.S. there was more room for both officer specialists and ser-

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[4] A famous case is the assassination of one of the strongest leaders of army modernization, Maj Gen Tetsuzan Nagata, by Lt Col Saburo Aizawa in July 1935. Aizawa was abetted and tacitly encouraged by senior officers who successfully shielded him until a failed coup attempt in February of 1936 brought a change in army régime, whereupon Aizawa was convicted and executed along with the rebels. See James B. Crowley, *Japan's Quest for Autonomy: National Security and Foreign Policy, 1930-1938*, Princeton: Princeton University Press, 1966, pp. 266-71.

vice-connected civilian technologists to advance and pursue ideas that did not obviously fit into doctrinal concepts. This seems to be the major reason why the U.S. developed radar, for instance, while Japan did not.

At the same time, where the Japanese did get their guiding doctrine right their intense efforts to implement it effectively paid important dividends in many areas. Had they devoted the same kind of attention to operational movement and logistics that they did to carrier operations, for instance, their forces would have been formidable indeed.

It is worth noting as well how much the U.S. military benefited from its intelligent cooperation with American industry. Since there was little real "defense" industry that was dependent on military business, the services were often not in a strong position simply to issue orders as the Japanese did. But the U.S. services – particularly the USN – found a variety of areas in which they could provide financial incentives and technical help to industry in developing dual-use technologies with both military and commercial value. This had the added benefit of creating a pattern of military-industrial relationships which tended to open doors for receiving ideas from industry. The services here were taking good advantage of an asymmetrical opportunity, since Japan's industry lacked the breadth and depth of capabilities available in the U.S., and the concomitant financial strength to pursue options.

In a sense, Japan pursued conquest because it feared the full implications of social, political, and economic modernization. Its elites wanted change and progress, to be sure, but only on their terms and in ways that did not threaten what they perceived as the nation's foundations. But Japan's lack of modernity in these respects severely hampered the military transformation that would have been essential to succeed in conquest. The lesson seems to be that if we wish to ensure our lead in military strength over modernizing states who might wander onto the paths of conquest we must embrace and exploit modernity ourselves. This is not easy, for it means accepting chaotic pluralism, diversity, and change, and the effort to recognize and comprehend unfamiliar and complex phenomena.

Introduction

Most of the existing literature on historical military transformation examines isolated instances involving particular weapons systems and arms.[5] This has been productive of valuable insights but involves obvious limitations. In this paper I consider a case of multifaceted transformations over an extended period involving a number of organizations and institutions. This makes it possible to ask some questions that cannot sensibly be addressed in isolated cases, including:

- What is the relationship between the strategy of transformation and overall grand strategy?
- How does competition between two or more countries affect the course of their transformation efforts?

The case used here is that of Japan and the United States in the period from 1920 through the start of the war between them in De-

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[5] Notable and influential examples which refer to instances covered by this paper include Thomas C. Hone and Mark D. Mandeles, "Interwar Innovation in Three Navies: U.S. Navy, Royal Navy, Imperial Japanese Navy," *Naval War College Review.* (Spring 1987), pp. 63-83; Thomas C. Hone, Norman Friedman, and Mark D. Mandeles, *American & British Aircraft Carrier Development, 1919-1941,* Annapolis: Naval Institute Press, 1999; David E. Johnson, *Fast Tanks and Heavy Bombers: Innovation in the U.S. Army, 1917-1945,* Ithaca: Cornell University Press, 1998; Williamson Murray and Allan R. Millett (editors), *Military Innovation in the Interwar Period,* Cambridge: Cambridge University Press, 1996; Stephen Peter Rosen, *Winning the Next War: Innovation and the Modern Military,* Ithaca: Cornell University Press, 1991. William H[ardy] McNeill, *The Pursuit of Power: Technology, Armed Force, and Society since A.D. 1000,* Chicago: University of Chicago Press, 1982 is the classic broad study of transformation generally. Although varying widely in outlook and methodology, these share with this paper a focus on drawing general lessons from historical cases. More purely historical treatments are very numerous, and many are cited in this paper.

cember, 1941. It is an especially interesting and relevant case for several reasons:

- The period has long been identified as one of particular interest for studies of transformation.
- The case is relatively well documented.
- Because the rivals, the U.S. and Japan, identified each other as principal potential opponents even before the start of the period, we have the relatively unusual situation that lapses in transformation are not much confounded with lapses in strategic foresight.
- As the first state of non-European origin to join the Eurocentric state system and global economy, Japan is in some respects a model of other modernizing and rising powers.

The path to war

Japan had been an essentially feudal state, self-isolated to a large extent not only from the West but from its Asian neighbors, under the Tokugawa Shogunate from 1600 to the 1850s.[6] The Shogunate was brought down in a revolution mounted by minor officials of several feudal fiefdoms which harbored hostility to the ruling Tokugawa dynasty. In the so-called Meiji Restoration, they proclaimed a new order in 1868, using the ancient but long-powerless imperial house as a rallying symbol for national unity. After a decade of internal strife and disorder, a relatively small group of "Meiji oligarchs" established effective control of Japan and launched on an intensive

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[6] Surveys of Japanese history in the period from 1600 to the present are provided by Marius Jansen, *The Making of Modern Japan,* Cambridge: Belknap Press of Harvard University Press, 2000; and Mikiso Hane, *Modern Japan: A Historical Survey,* Second edn., Boulder: Westview Press, 1992. The period from the dawn of the Meiji state to World War II is the focus of John Benson and Takao Matsumura, *Japan, 1868-1945: From Isolation to Occupation,* Harlow, England: Longman, 2001.

program of political centralization and economic modernization. This was the "golden age" of European imperialism in Asia and they consciously modeled their state on European norms of that era, particularly those of the newly-emergent German Empire. In particular, they assimilated the expansionist and imperialist ethos then common in Europe.

Change was rapid in the United States at the same time, of course, as it progressed from an isolated and relatively primitive frontier state to the world's largest and most progressive economic power. Both countries were aided in their growth and thrust toward closer contact with others by the rapid development of long-distance transport and communications. Both faced unaccustomed challenges of foreign relations. They accumulated frictions with each other and with other distant nations.[7]

Strategically, Japan faced west, toward the Continent of Asia. There potential threats loomed from the maritime powers of Western Europe which had established colonial enclaves in China, from China itself, chaotic but vast, and from the expansive empire of Russia. But because so much of North-East Asia was politically and economically undeveloped, Japan also saw vast opportunities for territorial and economic empire.[8] After vanquishing China and Russia in limited conflicts in 1895 and 1905, adding Taiwan, Korea, and strategic portions of Southern Manchuria to its empire, and establishing an alliance with Britain, Japan began to look uneasily over its

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[7] For a survey of relations between the U.S. and Japan from an American viewpoint see Walter LaFeber, *The Clash: U.S.-Japanese Relations Throughout History*, New York: W. W. Norton & Co., 1997. Japanese-American historian Akira Iriye has written extensively on relations between the U.S. and Japan as well as China from a multinational viewpoint, drawing on multiarchival sources. See his *Across the Pacific: An Inner History of American-East Asian Relations*, New York: Harcourt, Brace & World, 1967; *After Imperialism: The Search for a New Order in the Far East, 1921-1931*, Cambridge: Harvard University Press, 1965; and *Pacific Estrangement: Japanese and American Expansion, 1897-1911*; Cambridge: Harvard University Press, 1972.

[8] W[illiam] G. Beasley, *Japanese Imperialism, 1894-1945*, Oxford: Clarendon Press, 1987 surveys Japan's empire and imperialism.

shoulder at the United States, which had recently acquired the Philippines as a colonial territory in an unplanned sequel to its Cuban-oriented war with Spain, and begun to build a modern navy.

Portions of the U.S. business community had long looked to China as a vast potential market. In practice, Japan was a better trading partner, but China's size was mesmerizing.[9] At the same time, immigration of industrious and alien Japanese (and Chinese) to the U.S. West Coast and a general rise of racism in the U.S. led to racial tensions. These and other frictions mounted sharply in the first decades of the 20th century. By 1907, each nation had identified the other as a potential military and especially naval threat. After World War I, each was at least the nominal principal prospective national enemy of the other for military planning purposes.[10]

Japan and the United States were both drawn into the European war of 1914-1918, transforming it into the First World War. (The basis and nature of their participation was different in ways that had important effects on their subsequent military transformations, a difference I will explore further below.) Both sat on the victor's side of the peace table. Each found its position much strengthened relative to the European powers in the post-war era.

The nations of Europe had for centuries been forced to face a wide variety of intra-European interstate conflicts and had developed considerable expertise in conducting foreign relations. Japan and the United States, long relatively isolated, had far less experience,

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[9] For American views of the China market as well as its realities see Peter Schran, "The Minor Significance of Commercial Relations between the United States and China, 1850-1931," in *America's China Trade in Historical Perspective: The Chinese and American Performance*, edited by Ernest R. May and John King Fairbank, Cambridge: Harvard University Press, 1986.

[10] Sadao Asada, "From Washington to London: The Imperial Japanese Navy and the Politics of Naval Limitation, 1921-1930," *Diplomacy and Statecraft*, Vol. 4, No. 3 (Nov 1993), pp 149-150; Edward S. Miller, *War Plan Orange: The U.S. Strategy to Defeat Japan, 1897-1945*, Annapolis: Naval Institute Press, 1991, p. 21; Louis Morton, *Strategy and Command: The First Two Years*, Washington: Center of Military History, U. S. Army, 1962, pp. 28-29.

even though each made efforts to learn from Europe. Neither nation was well prepared to deal with the conflicts that emerged between them in the 1920s. Moreover, these conflicts were exacerbated by a variety of internal problems in both nations.

A series of frictions and crises fueled mounting U.S.-Japanese frustration, suspicion, and hostility throughout the 1920s and 1930s. In 1924 the United States passed the Japanese Exclusion Act, specifically barring immigration from Japan, thereby gratuitously cutting the ground from under those in Japan who had urged reliance on American goodwill and fairness. As a still largely agrarian economy Japan was particularly hard hit by the worldwide agricultural recession of the late 1920s, inevitably fuelling resentment of foreigners suspected of exploiting the nation's weakness. The Great Depression of the 1930s hit the U.S. with special severity and led many Japanese (and others around the world) to conclude that free-market democracy had been proven a failure. At the same time, the rise of Hitler and increasing aggressiveness by Mussolini in Europe led to unease in the U.S., while Stalin's program of massive industrialization alarmed many in Japan.

In Japan these currents created a sense both of threat and opportunity which combined with internal political developments to bring expansionist and even adventurist elements to power. In the U.S., the political focus turned even more inward and away from foreign affairs in the early and mid 1930s.

Breakdown of the post-WW I security structure

In the wake of World War I, major nations had exerted themselves to construct a security framework that would prevent such calamities in the future. While the U.S. ultimately did not join its own creation, the League of Nations, there was cooperation with it through the 1920s. By the American-sponsored Pact of Paris, or Kellogg-Briand Pact, nations formally outlawed war as an instrument of national policy. Even maverick states did not break ranks. Fascist It-

aly subscribed to the Pact of Paris as well as the Locarno Pact, guaranteeing the frontiers of states in Western Europe. While remaining formally aloof, and continuing to agitate for revolution in the non-communist world, the USSR made no threats of a military nature against Western Europe.[11]

Although Europe was the principal focus of pacification efforts, Asia and the Pacific also were tied into the security net. The U.S. sponsored the Washington system of treaties which bound it and Japan, with others, to respect China's integrity and provide free trade opportunities as well as refraining from fortifying island possessions and limit naval armaments. Naval limitations were reaffirmed and expanded in the Treaty of London. American leaders came to believe that their nation could exercise effective moral leadership in the cause of world peace without compromising its tradition of aloofness from direct foreign involvement. America's involvement in World War I was seen by most as a distasteful and futile departure from the nation's true course.[12]

Japan felt far less secure. Aside from the internal strains of modernization (including the rise of groups devoted to various imported ideologies) Japanese leaders were very concerned about the effects of turmoil in China on Japanese prosperity and security, about the efforts of Stalin and his Comintern to gain influence in China and bordering territories, and the direct threat posed by Soviet military forces in the Far East. Many Japanese, particularly in the army, became convinced that only expansion in Northeast Asia could secure the nation from external threats, economic decline, and internal turmoil.

As a result of its victory over Russia in 1905 Japan had taken over Russia's long-term lease on China's Kwantung (Liaodong) Penin-

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[11] Raymond J. Sontag, *A Broken World, 1919-1939,* The Rise of Modern Europe, New York: Harper & Row, 1971, pp. 86-138.

[12] Akira Iriye, *The Globalizing of America, 1913-1945,* The Cambridge History of Foreign Relations, Vol. III, Cambridge: Cambridge University Press, 1993, pp. 58-87 and James B. Crowley, *Japan's Quest for Autonomy,* pp. 35-66.

sula, ownership of the South Manchurian Railway that terminates there, and rights to garrison both the leased territory and the railway right of way.[13] In September, 1931 mid-level officers of the staff of the so-called Kwantung Army, as the garrison force was called, manufactured a pretext for attacking the Chinese warlord who then controlled Manchuria. Even though this aggression had not been authorized by their superiors, the Japanese Army as a whole supported it and left the civilian leadership with no choice. By February, 1932, Japan had conquered all of Manchuria and proclaimed the founding of "Manchukuo", a nominally independent empire that was in fact a creature of the Kwantung Army. Censured by the League of Nations for its violation of the Pact of Paris, Japan withdrew from the League. No major power other than Japan's allies ever recognized the legitimacy of the conquest, but no action of substance was taken. This so-called Manchurian Incident marked the effective end of collective or cooperative security arrangements; it was a wellspring of a current of aggression that Italy and Germany would soon join.[14]

Joining the Axis

Hitler was appointed chancellor of Germany early in 1933 and by the end of 1934 had formally amalgamated both that office and the presidency under himself as *Füher.* He marched into the Rhineland in defiance of the demilitarization clauses of the Versailles Treaty in July, 1936, quickly provided open support to the Spanish fascists in the civil war that broke out two weeks later, and joined Mussolini (who had just conquered Ethiopia) in their "Axis" in October.

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[13] Concessions of these sorts were held by a number of European powers, having been granted at sword's point by the weakened Chinese Empire.

[14] James William Morley, editor, *Japan Erupts: The London Naval Conference and the Manchurian Incident, 1928-1932,* Japan's Road to the Pacific War: Translation of Selected Portions from *Taiheiyō sensō e no michi: kaisen gaikō shi,* New York: Columbia University Press, 1984, pp. 119-335.

Many senior Japanese officials and army officers had longstanding ties to Germany and many others were attracted to Hitler's virulent anti-communism and rejection of the existing international order. Moreover, Japan was finding itself shunned in most other capitals in the wake of the Manchurian takeover. After lengthy negotiations both with the Nazi government and within its own ranks, Japan concluded the Anti-Comintern Pact with Germany in November, 1936. Those who had successfully promoted it in Japan had miscalculated the reactions of other states; Japan found itself more isolated after concluding the pact than before.[15]

In July, 1937, a minor clash occurred between Chinese and Japanese troops at the Marco Polo Bridge outside Beijing. Once again, Japanese officers on the scene escalated the conflict without reference to Tokyo. With the Chinese Nationalists unwilling to back down, a major conflict – termed the China Incident – quickly developed.[16] The Japanese army was usually able to best Chinese forces in open combat but could find no way to conquer and hold China's vast spaces in the face of unrelenting Chinese opposition. The presence of many Europeans and Americans in China, together with light Western military forces dedicated to their protection, led to a num-

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[15] James William Morley, editor, *Deterrent Diplomacy: Japan, Germany and the USSR, 1935-1940*, Japan's Road to the Pacific War: Translation of Selected Portions from *Taiheiyō sensō e no michi: kaisen gaikō shi*, New York: Columbia University Press, 1976, pp. 3-111.

[16] While Japan's march to war has not been as richly studied as Germany's, the literature is too extensive for concise survey. For a relatively recent and comprehensive historigraphical essay see Michael A. Barnhart, "The Origins of the Second World War in Asia and the Pacific: Synthesis Impossible?" *Diplomatic History*, Vol. 20, No. 2 (Spring 1996), pp. 241-60. Barnhart surveys and places in context the majority of the works cited here. A useful brief summary is combined with a bibliographical essay in Akira Iriye, *The Origins of the Second World War in Asia and the Pacific*, London: Longman, 1987. For a survey of Japanese works and views see Takeshi Matsuda, "The Coming of the Pacific War: Japanese Perspectives," *Reviews in American History*, Vol. 14, No. 4 (Dec 1986), pp. 629-52.

ber of more-or-less accidental incidents, including the bombing and sinking of the gunboat U.S.S. *Panay* in December, 1937.[17]

The tenor of relations between Japan and the United States soured greatly in this period. It was a time of American popular sympathy and idealism about China generally, leaving many predisposed to see Japan in the wrong, and the history of the Manchurian takeover had in any event naturally left suspicions in many minds. Many in Japan, led by Prime Minister Konoe, embraced an ideology of "pan-Asianism" in which Japan was destined to lead all the peoples of Asia to realize their aspirations of national political freedom under Japanese guidance. They saw this as a noble ideal justifying Japanese expansionism and resented America's dismissal of it, while to Americans it seemed no more than a cynical rationalization for self-interested aggression.[18]

While the war in China ground on, Hitler seized Austria, the Sudetenland, and the balance of Czechoslovakia. Finally, in September, 1939, he initiated general war in Europe by invading Poland. Germany's military strength combined with Hitler's aggressive policies and statements about world domination concerned many in the United States. The response was split between those who hoped to seal America off from a warring world and those who increasingly felt that the U.S. would have to stand with other democratic countries in containing aggression. President Franklin D. Roosevelt inclined to the latter view, but many prominent political figures remained committed to non-involvement.[19] Nevertheless, the specter

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[17] Alvin D. Coox, *Year of the Tiger*, Tokyo: Orient/West, 1964 explores the early part of the Sino-Japanese conflict and its impact on Japan's relations with the West.

[18] Peter Duus, "Imperialism Without Colonies: The Vision of a Greater East Asia Co-Prosperity Sphere," *Diplomacy and Statecraft*, Vol. 7, No. 1 (Mar 1996), pp. 54-72.

[19] Wayne S. Cole, *Roosevelt and the Isolationists, 1932-1945*, Lincoln: University of Nebraska Press, 1983 is the standard account.

of war in Europe and Asia prompted some modest steps toward American rearmament, principally in ships and aircraft.[20]

There was nothing modest about Japanese rearmament. Even before the outbreak of war in China, the nation had expanded its mobilization efforts to approach the capacity of the economy. Army efforts were justified by the danger from Russia but the Navy pointed across the Pacific to the supposed threat posed by the United States.[21]

The Nazi conquest of most of Western Europe in the spring and summer of 1940 shocked and alarmed the U.S. and led to enactment of a 70% increase in naval strength in June and the nation's

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[20] Dean C. Allard, "Naval Rearmament, 1930-1941: An American Perspective," in *The Naval Arms Race, 1930-1941,* edited by Jürgen Rowher, Stuttgart: Bernard & Graefe Verlag, 1991; Constance McLaughlin Green, Harry C. Thomson, and Peter C. Roots, *The Ordnance Department: Planning Munitions for War,* Washington: Center of Military History, U. S. Army, 1955, pp. 30-82; Irving Brinton Holley, Jr., *Buying Aircraft: Matériel Procurement for the Army Air Forces* Washington: Department of the Army, 1964, pp. 6-208; Maurer Maurer, *Aviation in the U.S. Army, 1919-1939,* Washington: Office of Air Force History, 1987, pp. 345-438; Russell F. Weigley, "The Interwar Army, 1919-1941," in *Against All Enemies: Interpretations of American Military History from Colonial Times to the Present,* edited by Kenneth J. Hagan and William R. Roberts, New York: Greenwood Press, 1986.

[21] Michael A. Barnhart, *Japan Prepares for Total War: The Search for Economic Security, 1919-1941,* Ithaca: Cornell University Press, 1987, Chapts. 3, 5, and 7-9; Edward J. Drea, *In the Service of the Emperor: Essays on the Imperial Japanese Army,* Lincoln: University of Nebraska Press, 1998, pp. 1-13; David C. Evans and Mark R. Peattie, *Kaigun: Strategy, Tactics, and Technology in the Imperial Japanese Navy, 1887-1941* Annapolis: Naval Institute Press, 1997, pp. 353-423; Headquarters Military History Section, Army Forces Far East, *Outline of Naval Armament and Preparations for War, Parts I-III,* Japanese Monographs Nos. 145, 149 and 160, Washington: Office of the Chief of Military History, Department of the Army, [n.d.]; Mark R. Peattie, *Sunburst: The Rise of Japanese Naval Air Power, 1909-1941,* Annapolis: Naval Institute Press, 2001, pp. 77-101; Eiichiro Sekigawa, *Pictorial History of Japanese Military Aviation,* "PBS Book Club Edition," [London]: Ian Allan, 1974, pp. 84-110; and Saburo Toyama, "The Outline of the Armament Expansion in the Imperial Japanese Navy During the Years 1930-1941," In *The Naval Arms Race, 1930-1941.*

first peacetime draft in September, followed by Lend-Lease aid to Britain in March, 1941.

It also led Japan to emulate and ally itself with the seemingly all-conquering Hitler. The Japanese army had looked to Germany as its model since shortly after the German victory in the Franco-Prussian War 70 years before. To Japanese expansionists and imperialists, Hitler seemed nearly a soul-mate. With France and the Netherlands beaten by Germany and Britain seemingly next, the time appeared ripe to seize their rich colonial possessions in Asia. Moreover, the army had convinced itself that China would "see reason" and come to terms if its tiny trickle of Western aid were to be cut off.

But what about America? This was of little concern to the army, which held no high opinion of American military capacity.[22] While the navy also denigrated the Americans (a sentiment that the Americans returned, of course), they were somewhat wary of U.S. fleet strength nevertheless. After much discussion and bickering, Japan elected to ally itself with the Nazi-Fascist Axis, with the expectation that this would deter the U.S. from any interference. The Tripartite Pact was accordingly signed in September, 1940.

In so doing, Japan converted itself from a nuisance to a menace in the eyes of President Roosevelt, who was deeply apprehensive about Hitler. As 1940 changed to 1941 and Germany continued its seemingly inexorable progress of conquest the U.S. made efforts to detach Japan from the alliance, or at least weaken its hold; all were rebuffed.[23]

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[22] Michael A. Barnhart, "Japanese Intelligence Before the Second World War: 'Best Case' Analysis," in *Knowing One's Enemies: Intelligence Assessment Before the Two World Wars*, edited by Ernest R. May, Princeton: Princeton University Press, 1984, pp. 446-447, 454; Alvin D. Coox, "Flawed Perception And Its Effect Upon Operational Thinking: The Case of the Japanese Army, 1937-41," *Intelligence and National Security*, 5, No. 2 (Apr 1990), pp. 239-54; and Edward J. Drea, *In the Service of the Emperor*, pp. 32, 37, 69.

[23] Waldo Heinrichs, *Threshold of War: Franklin D. Roosevelt and American Entry into World War II*, Oxford: Oxford University Press, 1988, pp. 96-99.

FDR pursued a carrot-and-stick policy toward Japan, endeavoring to contain the Japanese threat through withholding oil and other resources, deter through military preparations, and coax Japan's leaders to see reason. He was determined to see Hitler defeated and destroyed but hoped to do so with American matériel and the military manpower of others. If that could be accomplished then Japan would be a manageable problem.[24]

Russia played an oddly pivotal role. The Japanese Army's leadership had viewed Russia as the main threat to Japan and its interests for decades, and its views were of course well known in Washington. The alliance with Germany had originally been specifically anti-communist and anti-Russian. Hitler's June, 1941 invasion of the USSR brought a sense of crisis in both Tokyo and Washington. To the IJA and its supporters it seemed that this might be Japan's chance at last to eliminate the Russian threat: if Stalin pulled his troops back from the Far East to fight Hitler then Japan might be

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[24] There is, of course, no definitive record of what Roosevelt actually thought or intended, so there is an element of speculation in this. It is, however the picture that emerges from the comprehensive study of his actions during the year prior to Pearl Harbor: Waldo Heinrichs, *Threshold of War.* See particularly pages 159-160, and also the succinct and pointed argument of Gerhard L. Weinberg, "Grand Strategy in the Pacific War," in *Pearl to V-J Day: World War II in the Pacific,* edited by Jacob Neufeld, William T. Y'Blood and Mary Lee Jefferson, Washington: Air Force History and Museums Program, 2000, especially pages 1-3, as well as Heinrichs' brief "Pearl Harbor in a Global Context," in *Pearl Harbor Revisited,* edited by Robert W. Love, Jr., London: Macmillan, 1995. At the time, of course, many isolationists were convinced that FDR actually sought to entice an attack as an excuse for war, and some of them and their intellectual heirs have never retreated from this thesis. See for instance Charles A. Beard, *President Roosevelt and the Coming of the War, 1941: A Study in Appearances and Realities,* New Haven: Yale University Press, 1948; and Charles Callan Tansill, *Back Door to War: The Roosevelt Foreign Policy, 1933-1941,* Chicago: Henry Regnery, 1952. For a more moderate and balanced modern recitation of the charges see, for instance, Stephen E. Ambrose, "'Just Dumb Luck': American Entry Into World War II," in *Pearl Harbor Revisited,* edited by Robert W. Love, Jr., London: Macmillan, 1995. Note, however, that Ambrose's citations are mostly to Heinrichs' *Threshold of War,* a close reading of which fails to sustain many of his key assertions.

able to defeat the remainder and seize much of Siberia. German and Japanese forces might meet and divide Russia between them.

President Roosevelt's concerns were a mirror image of the IJA's hopes. A Japanese stab in the back could be the factor that would lead to collapse of the Soviet Union and put Germany in control of Russia's vast resources. How could the West then hope to contain let alone defeat Hitler? With the need to constrain the IJA made much more urgent, the U.S. closed down all exports of oil to Japan and worked to dissuade other potential suppliers from filling the gap.

No choice but war

Stalin had good intelligence about Japanese thinking and knew perfectly well what the IJA had in mind. Despite the desperate situation in the west, he refused to withdraw forces from the east. By early fall the Japanese generals were forced to conclude that an invasion of Siberia would be impossibly risky, particularly with the army so tied down in China.

The Japanese Navy had long been interested in a "southern strategy" – an effort to gain control of the resources of Southeast Asia, and particularly the oil of Indonesia. With its own sources of oil, they believed, Japan could be truly independent of America. So long as it fixed its gaze on the USSR, the army rejected these ideas.

Now, having abandoned any notion of invading the Russian Far East in 1941, the Japanese generals turned their attention to the festering sore of China. They had beaten China's armies in battle, after all, so why would the Chinese not yield? It could only be, they imagined, that China was sustained by the trickle of American and British material support entering via various southern routes, and by the hope this held out of more substantial support. Cut off these routes and that hope, they reasoned, and the China problem would quickly be resolved. Then Japan would have the strength to settle matters with the Soviet Union.

These fantasies about the roots of Chinese intransigence meshed with others concerning the imminence of Hitler's defeat of Britain.

It was obvious that with Britain hard pressed in Europe and France and the Netherlands already under German occupation, the Asian possessions of these nations would be easy pickings. And once Britain was out of the picture, the Americans would surely "see reason", they imagined. Thus the IJA, for altogether different reasons, finally joined the IJN in advocating the principle of southern advance, although they remained far apart on the details.

The army had already taken advantage of the fall of France to the Germans in mid 1940 to make the first step, occupation of the northern part of the French colony of Indo-China (Vietnam). The army saw the road as open to seizure of much of Southeast Asia and its resources, but the navy was concerned that an attack on British colonies would prompt American intervention. These anxieties could not be voiced too forcefully, however, without suggesting that the admirals were afraid to meet the U.S. Navy. They were, but how could they acknowledge that they had spent so much of Japan's resources on a fleet that could not accomplish its main task? It would be the end of the IJN's influence in the nation's affairs, just as admission of inability to defeat China would be the end of the IJA's.

Events in Europe also stimulated a spread of pan-Asianist ideology within the army and government. There was heady talk of "gathering the eight corners of the world under one [Japanese imperial] roof." Surely the peoples of Asia, they reasoned, would welcome liberation from *fainéant* Western colonial rulers (which, the special case of the Philippines aside, they almost invariably did) and gladly accept Japanese leadership and direction in the effort to build a "Greater East-Asia Co-Prosperity Sphere" (which almost uniformly they decidedly did not).[25]

The cutoff of oil in July, 1941 did not threaten any sort of immediate ruin, or even curtailment of Japan's military capacity. Reserves on hand were estimated to suffice for two years of operations at war-

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[25] The Philippines was a special case, at least in large measure, because it had already received firm U.S. guarantees of independence by 1946.

time rates.[26] But the navy leaders were very concerned about the longer term. In the wake of the fall of France the U.S. had embarked on a massive fleet build-up which would make the USN overwhelmingly superior to the IJN by 1944. The Japanese Navy, on the other hand, was nearly at its peak – there simply were no resources for extensive further fleet expansion. If ever the navy was to confront its nemesis, now was the time.

The navy agreed to join the army in an advance to the south in order to seize resources but only on the condition that it conduct a preemptive attack on Pearl Harbor to forestall immediate USN intervention in the Western Pacific. The army, conditioned by years of navy boasting to the notion that it could handle the U.S. fleet as it had that of the Czar, gladly agreed.

Whatever view was taken of the immediate military balance, it was evident that America's ultimate war-making potential was vastly greater than Japan's. A few Japanese officers and officials warned openly of the risks and inconsistencies in Japan's plans but all cautionary voices were silenced or ignored.[27] In essence the arguments came down to nothing more than, "We have no choice: we shall do our best and surely that will be enough."

What was this threat that gave them no choice, a threat so awful as to justify any risk? Fundamentally, the military leaders who controlled Japan's policy in 1941 feared the destruction of military power within Japan more than the risk of the destruction of Japan itself. Having climbed to the summit of political power on a program of expansion and control over China they could not back

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[26] Evans and Mark R. Peattie, *Kaigun*, p. 410.

[27] See for instance Michael A. Barnhart, "Japanese Intelligence Before the Second World War"; Kimitada Miwa, "Japanese Images of War with the United States," in *Mutual Images: Essays in American-Japanese Relations*, Vol. 7, edited by Akira Iriye, Cambridge: Harvard University Press, 1975; Mark R. Peattie, *Ishiwara Kanji and Japan's Confrontation With the West*, Princeton: Princeton University Press, 1975, p. 340; Sadao Seno, "A Chess Game With No Checkmate: Admiral Inoue and the Pacific War," *Naval War College Review*, (Jan-Feb 1974), pp. 26-39.

down from it without surrendering the institutional place of the armed services within Japan, and this they could not contemplate.[28] It is important to recognize this because it had its effects on military transformation, the subject to which I now turn.

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[28] This is a relatively unconventional view on an important topic which it would be out of place to explore in depth in this paper. My views are fairly close to those expressed very clearly in Jack [L] Snyder, *Myths of Empire: Domestic Politics and International Ambition,* Ithaca: Cornell University Press, 1991, especially pp. 112-152.

Transformations

Wars are great teachers of military lessons and few have been studied more intensively than World War I. Both Japan and the U.S. had participated in the conflict, although in very different ways.

Japan had concluded an alliance with Britain in 1902 and renewed it in 1905 and 1911, and was thus obligated to aid Britain in the European War. Powerful figures in Japan would nevertheless have been more comfortable to have stayed out of the war, or even to have entered on the side of Germany, which had long mentored the Japanese army. In the event, decisive action by Japan's British-leaning foreign minister led to prompt declaration for Britain. But there still remained the question of just what Japan would do in the war. The alliance was very much a *mariage de convenance* between two nations whose interests converged only at certain points and Britain neither expected the help that would be most valuable nor greatly valued that which Japan was most ready to offer.[29] As a result, Japan's only experience of European combat came in antisubmarine operations in the Mediterranean.

Like Japan, the United States profited from supplying the Allies with staples and materials of war. But the U.S. had deliberately avoided ties with any European states and its populace and leadership were resolved to stay out of the conflict. Nevertheless, strategic logic combined with misguided and clumsily executed German policy to bring America into the war as a member of the Allies in April, 1917, 32 months after its beginning. In a little more than a year the U.S. raised a great army and deployed it to the fighting front in France, where it helped provide the impetus that defeated Imperial

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[29] Frederick R. Dickinson, *War and National Reinvention: Japan in the Great War, 1914-1919*, Cambridge: Harvard University Asia Center and Harvard University Press, 1999, especially pp. 1-83.

Germany six months later. At the same time, the U.S. Navy participated actively in the work of patrol and antisubmarine warfare at sea. Thus the U.S. armed forces gained significant experience of modern warfare in all its dimensions.

The armed services after World War I

It was in the wake of the war, with Germany and Russia both much diminished in power by defeat and internal turmoil, that America's and Japan's navies – and to a lesser extent their armies – turned to focus strongly on one another, with the war's lessons in mind. As to what the lessons were, there was some agreement and some disagreement. At this point it will be helpful to sketch both the state of each service as well as its thinking.

America's naval forces: the USN and USMC

With the rise of America's industrial power late in the 19th century the nation had embarked on construction of a strong and modern navy. Its purposes were not clearly spelled out but it reflected a sense that technology was shrinking the vastness of the oceans and bringing America strategically nearer to Eurasia. During the First World War but prior to America's entry Congress had passed the Naval Act of 1916 authorizing (but not appropriating funds for) a massive buildup of the fleet to create "a navy second to none" in the world. After April, 1917, construction of battleships was suspended in favor of destroyers and other urgently-needed antisubmarine vessels, but the U.S. Navy (USN) nevertheless finished the war with a battle fleet nearly as large as Britain's and more modern. It also had a considerable force of destroyers, although no modern cruisers.

The Republican candidate, Warren G. Harding, won election to the presidency in 1920 on a platform of "return to normalcy", including a sharp reduction in armaments and military spending. With little prospect in any event of Congressional appropriations to complete the 1916 program, Secretary of State Charles Evans Hughes elected to bargain it away as part of negotiations to contain Japan (princi-

pally) and other colonial powers in Asia and to detach Britain from its ties to Japan, all while avoiding major U.S. commitment or expense. The resulting Washington Conference of 1921-1922 produced three major multilateral treaties: the Four-Power Treaty by which the U.S., the British Empire, France, and Japan agreed to support the status quo in Asia (supplanting the Anglo-Japanese bilateral commitment in a much weaker form); the Nine-Power Treaty to guarantee China's independence (but not too much independence) and free Western and Japanese access to Chinese markets and resources (the American-British "Open Door Principle"); and the Five Power Treaty which limited battleship and carrier tonnage and prohibited fortification of insular possessions in the Pacific (except for Hawaii and Singapore). The treaties were greeted enthusiastically by the American public and world opinion at large as a major step toward world peace and prosperity.

The Nine-Power Treaty was soon proven to be a dead letter because no one was really very committed to it.[30] The Four-Power Treaty never amounted to anything more than vague good intentions and expired quietly after its ten-year term. The Five-Power naval treaty was intensely unpopular with many American and Japanese naval officers (although some thoughtful senior officers saw much value in it). Nevertheless, it was followed by an unsuccessful 1927 effort at extending its provisions, the 1930 London Conference at which its term was extended and expanded to cover other vessels, and the 1936 London Conference which produced a treaty that was dead on arrival due to Japan's refusal to adhere to it. The whole naval disarmament enterprise has remained controversial down to the present day.[31]

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[30] Akira Iriye, *After Imperialism.*

[31] Accounts of the conference and its effects are provided by Samuel Flagg Bemis, *A Diplomatic History of the United States,* New York: Henry Holt & Co., 1955, pp. 690-702 and Akira Iriye, *The Globalizing of America, 1913-1945,* pp. 75-78. Details of the naval negotiations in Washington are found in A[rthur] D[avidson] Baker, III, "Battlefleets and Diplomacy: Naval Disarmament Between the Two World Wars," *Warship International,* No. 3 (1983), pp 217-26 and, at much greater length, in Harold Sprout and

The 1922 treaty committed all signatories to dispose of some existing battleships and prohibited the United States and Japan from building any new units.[32] Its other tonnage limitation, that on aircraft carriers, had a very different effect, for it was a limit to build up to, not to scrap down to. The few carriers then existing or under construction were excluded as experiments of negligible military value. Thus the 135,000 tons allotted to Britain and the U.S. and the 81,000 for Japan represented room to create a new force.[33] For this reason, many have argued that the treaty had positive effects on development of carrier aviation.[34]

Margaret Sprout, *Toward a New Order of Sea Power: American Naval Policy and the World Scene, 1918-1922*, second edition, Princeton: Princeton University Press, 1943. For contemporary naval views in Japan see Sadao Asada, "From Washington to London." For U.S. naval opinion see Dudley W[right] Knox, *The Eclipse of American Sea Power*, New York: American Army and Navy Journal, 1922, as well as the overall evaluations in A. D. Baker, III, "Battlefleets and Diplomacy," pp. 246-47 and Ernest Andrade, Jr., "The United States Navy and the Washington Conference," *The Historian*. 31, (1969), pp. 345-63. Recent evaluations include Jon T. Hoffman, "Naval Arms Control Wins," United States Naval Institute, *Proceedings*, (Jul 1991), pp. 33-6 as well as Manley R. Irwin, "The Naval Policies of the Harding Administration: Time for a Reassessment?" *International Journal of Naval History*, Vol. 1, No. 1 (Apr 2002).

[32] At Japan's insistence, it was allowed to keep the new battleship *Mutsu*, already commissioned. In compensation, the U.S. got to complete two of the many ships it had under construction while Britain, which had scarcely any new ships, gained the right to construct two of modest size. France and Italy also came under the construction ban.

[33] Tonnage figures in the treaty are expressed in "standard tonnage" terms, a concept developed for the purpose by the Americans. This represents the displacement of the ship outfitted and ready for war but with no fuel or other consumable liquid loads. This was a definition which worked somewhat in favor of longer-ranged ships with large fuel loads and thus held obvious appeal for the USN, which saw its needs in transoceanic terms.

[34] See for instance Mark Allen Campbell, "The Influence of Air Power Upon the Evolution of Battle Doctrine in the U.S. Navy, 1922-1941," Master's thesis, University of Massachusetts, Boston, 1992, pp. 34-37.

It certainly had a great effect on the direction and pace of cruiser development. Prior to about 1910 the designation of cruiser had been applied to a diverse miscellany of ships. The largest ones, generally referred to as armored cruisers, were typically fairly close to the size of contemporary battleships, with lighter armament and protection but a margin of a few knots in speed. Others ranged down in size to no more than 20% of the displacement of battleships, with little or no protection, light armament, and perhaps five or six knots of speed margin. The USN had some armored cruisers but very few lighter types; only the ten 7,000 ton "scout cruisers" ordered in World War I and completed early in the 1920s were at all modern.

Along with the first all-big gun battleship, HMS *Dreadnought,* Britain introduced the battlecruiser, a ship of comparable size which mounted guns of the same caliber but fewer in number, had much lighter protection, and could match a light cruiser's speed. After some hesitation, the USN decided to build a class of battlecruisers under the 1916 authorization. These were incomplete at the time of the Five-Power Treaty, which forbade their completion. However, two of them were permitted to be converted to the navy's first effective aircraft carriers.

The treaty defined as a "capital ship" any over 10,000 tons in standard displacement or armed with guns of more than 8 inch caliber. Since no limits were placed on construction of non-capital ships, while that of carriers was limited and that of others virtually banned, much interest naturally focused on developing cruisers of 10,000 tons armed with 8 inch guns – the "treaty cruiser."

The London Treaty of 1930 established limits on cruiser tonnage and subdivided the category into two tiers, one limited to 8 inch guns and the other to 6 inch. The former naturally came to be called heavy cruisers and the latter light cruisers. Even though the United States had, through its drafting of the provisions of the Five-Power Treaty and heavy influence in those of the London Treaty,

set the terms of cruiser building, it was rather late in constructing significant numbers of these ships.[35]

The London Treaty also limited tonnage of destroyers and submarines. The navy had built large numbers of destroyers in World War I and embarked on no more construction of this type until the 1930s. There was also a substantial legacy of World War I vintage submarines, but American subs had fallen behind in technology, as revealed by examination of surrendered German U-boats after the war, and this stimulated a modest program of new construction.

World War I had produced a single major action between the main British and German battlefleets, the Battle of Jutland fought in the North Sea on 31 May 1916.[36] While the results were not very decisive in a tactical sense, with only a few ships lost on either side (and somewhat more on the British side than on the German), they were in the strategic sense of putting an end to German attempts to use their battlefleet as a force in the war. Indeed, even utter annihila-

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[35] Ernest Andrade, Jr., "Arms Limitation Agreements and the Evolution of Weaponry: The Case of the 'Treaty Cruiser'," in *Naval History: The Sixth Symposium of the U.S. Naval Academy*, edited by Daniel M. Masterson, Wilmington, Delaware: Scholarly Resources, 1987; *idem*, "The Cruiser Controversy in Naval Limitations Negotiations, 1922-1936," *Military Affairs*, Vol. 48, No. 3 (Jul 1984), pp. 113-20; Norman Friedman, *U.S. Cruisers: An Illustrated Design History*, Annapolis: Naval Institute Press, 1984, pp. 106-251; Robert Gardiner and David K. Brown, editors, *The Eclipse of the Big Gun: The Warship, 1906-45*, Conway's History of the Ship, London: Conway Maritime Press, 1992, pp. 55-70; and Christopher C. Wright, "Comparative Notes on U.S. Treaty Cruiser Design," *Warship International*, No. 4 (1980), pp. 311-32.

[36] Sketches of the action at Jutland and the other battles referred to in this paper may be found in E. B. Potter, editor, *Sea Power: A Naval History*, 2nd edition Annapolis: Naval Institute Press, 1981 as well as Helmut Pemsel, *A History of War at Sea: An Atlas and Chronology of Conflict at Sea from Earliest Times to the Present*, Trans. by D. G. Smith, Annapolis: Naval Institute Press, 1977. For actions in which the IJN participated (which of course does not include Jutland), more analytical accounts may be found together with citations of more extended works in David C. Evans and Mark R. Peattie, *Kaigun*.

tion of the German fleet would have been only marginally more valuable to Britain in strategic terms.

The U.S. Navy's leaders generally took Jutland as confirming the central role of the battleship in modern naval war and studied the battle for lessons. There were other lessons that they drew from the conflict, however, including the power of the submarine and the airplane.

The Marine Corps was at that time under the general jurisdiction of the Navy and not the independent armed service that it is today. It had long served largely as a ship's police for the navy, and to provide small armed shore parties. In the wake of the Spanish-American War, with its acquisition of overseas territories and bases, Marine Corps forces took a more prominent role. One innovation was the formation of an Advanced Base Force, intended to defend and if necessary seize bases for naval use.[37]

In World War I a hastily-assembled marine brigade had been incorporated into the American Expeditionary Force. Fighting under army command it had been the first American unit to see intense combat and had distinguished itself. But such service proved only that the marines were very good soldiers and did nothing to bolster the argument for a Marine Corps as separate from the Army.

After World War I Japan was awarded a League of Nations "Mandate" to occupy the formerly German-held islands of the Central Pacific north of the Equator (with those to the south going to Britain and Australia). In one sense these formed a barrier to a U.S. naval force attempting to move westward to engage the Japanese and relieve or retake the Philippines in war. But in another they afforded an opportunity, for if they could be seized then they could provide essential bases.[38] Many Navy officers were ambivalent about

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[37] See Allan R. Millett, *Semper Fideles: The History of the United States Marine Corps,* New York: Macmillan Publishing Co., 1980. While Millett covers the entire history of the Marines, he manages to treat the institutional development of the Corps in peacetime quite well.

[38] Edward S. Miller, *War Plan Orange,* pp. 110-111.

seizing bases, hoping that the need could be avoided in one way or another, and many Marine leaders looked on it as simply an added mission that detracted from better established duties. But in the early 1920s the Navy formally requested that the Marines take it on and, after a bit of hesitation, the Marines responded positively.[39]

Japan's navy: the IJN

The Americans had more or less inherited their maritime and naval traditions from their British forebears. Japan's situation was different. Before about 1600 the Japanese were infamous throughout the seas of East and Southeast Asia as fearsome pirates. Regular Japanese naval activity, however, was sparse and irregular, and no standing navy was kept. Out of concerns about domestic political stability the Tokugawa Shogunate banned all overseas travel by Japanese and most foreign intercourse of any kind through a series of decrees beginning in 1633. These remained in effect for more than two centuries.

The Meiji oligarchs were determined to put Japan on an equal footing with the West and saw a navy as one necessary element. At that point, in the late 19th century, Britain's Royal Navy (RN) was the world's strongest and Japan adopted it as a model for its navy, usually referred to as the Imperial Japanese Navy (IJN).[40]

The IJN's victories in the 1894-95 Sino-Japanese War and 1904-05 Russo-Japanese War gave it a solid tradition of its own, and especially the crushing defeat of a Russian fleet under Admiral Rozhdestvenski by Admiral Togo in the Battle of Tsushima on 27 May 1905.

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[39] Jeter A. Isley, and Philip A. Crowl, *The U.S. Marines and Amphibious War: Its Theory, and Its Practice in the Pacific,* Princeton: Princeton University Press, 1951, pp. 21-33; and Allan R. Millett, *Semper Fideles,* pp. 320-2.

[40] The standard work on the IJN and its development from beginning to end is David C. Evans and Mark R. Peattie, *Kaigun.* It is supplemented with respect to the IJN's air arm by Mark R. Peattie, *Sunburst.*

Rozhdestvenski had command of the Russian Baltic Fleet which had steamed the immense distance of 18,000 nmi around the Cape of Good Hope to reach Asian waters in an attempt to relieve the besieged garrison of Port Arthur on the Kwantung Peninsula. Port Arthur fell to the Japanese army while he was still *en route,* but he was ordered on to reinforce Vladivostok. This obliged him to take his fleet through one or another of the restricted straits into the Sea of Japan. Togo intercepted him, as Rozhdestvenski had anticipated, while the Russians were transiting the Tsushima Strait.

At Jutland the Germans, lacking good intelligence, blundered into an encounter not altogether unlike that forced on the Russians at Tsushima. But the German commander, Admiral Sheer, was able to extricate his fleet by turning about and steaming for his nearby base, covering his retreat with threats of torpedo attack. Rozhdestvenski, with his nearest base some 18,000 nmi away, had no such option. Moreover the German ships, having just sortied, were in good condition with fresh and well trained crews, where the Russians were worn down by seven months away from base. Unlike the Germans, the Russians had unequivocal orders to head for Vladivostok and the admiral himself was wounded and incapacitated early in the action and so unable to alter the plan. Finally, the Japanese fleet was fresh but battle-tested and thoroughly trained. All of these factors told against Rozhdestvenski, whose fleet was all but annihilated.

In strategic terms Tsushima and Jutland were broadly equivalent, but Tsushima *seemed* the much greater victory because of its tactical decisiveness. Moreover, as Rozhdestvenski's fleet had been Russia's last card in the conflict, its defeat was followed swiftly by peace, giving it a broader sense of decisiveness, of having brought a desperate conflict to a successful conclusion. To gain another such magnificent victory became the great ambition of the IJN.

Viewed from that perspective, the United States was a potential foe not entirely unlike the Russia of 1905. Both nations were large and distant, with important but not vital interests in East Asia. Both had relatively large navies, but without established records or traditions of success in great fleet actions. If the United States were to war against Japan in Asia as Russia had, it too would need to send a fleet

a great distance in an effort to wrest control of Asian seas from a Japanese fleet already on the scene. And if it could not succeed in this, it too would be left with few military options against Japan and its forces in Asia.

The leaders of the IJN read the lessons of World War I and Jutland in generally the same way as their counterparts across the Pacific. They too saw battlefleets as continuing to dominate naval war, while recognizing the emerging power of aircraft and submarines.

In this light, the great expansion of the USN's battleship strength over the decade following Tsushima was a matter of concern. In response to this as well as the rebuilding of Russia's fleet, the IJN sought to build up its battlefleet. The government, increasingly influenced by the elected Diet (parliament) in this period, resisted the navy's financial demands, but the resulting building program was nevertheless substantial. World War I and the 1916 U.S. program added further impetus. By the early 1920s a full-fledged arms race seemed to be developing, with a focus on Japan and the U.S.

This of course led to the Washington Conference. The top leadership of the IJN judged that Japan simply had no chance of successfully competing head on with the U.S. and that their nation's interests would better be served by cooperation with their giant Transpacific neighbor. As in the U.S., however, a great many senior officers saw the agreement as a betrayal of their nation's defense needs. Their enduring and bitter resentment made an explosive mixture with the political power held by the IJN in Japan's system of government.[41]

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[41] Sadao Asada, "From Washington to London" and *idem*, "Japanese Admirals and the Politics of Naval Limitation: Kato Tamosaburo vs Kato Kanji," in *Naval Warfare in the Twentieth Century, 1900-1945: Essays in Honour of Arthur Marder*, edited by Gerald Jordan, London: Croom Helm, 1977. Another article by this author which is often cited in this context, "The Revolt against the Washington Treaty: The Imperial Japanese Navy and Naval Limitation, 1921-1927," *Naval War College Review*. 66, No. 3 (Summer 1993), pp. 82-97, is essentially identical to the first part of his "From Washington to London."

Japan had no close equivalent to the U.S. Marine Corps. The IJN did have a naval infantry force which raised and trained lightly-equipped battalion-size units that were sometimes referred to as marines, but this force lacked the institutional standing of the Marine Corps in the United States.

America's army

Lacking threats on the American Continent, the United States long saw little need of an army in the European sense. At the outbreak of World War I the U.S. Army had fewer than 100,000 troops.[42] America's first European conflict swelled the army to more than 4 million, 2.8 million of whom were draftees and more than half of whom served overseas. More than 100 thousand men died in war service, including more than 50,000 killed in action, and more than 200 thousand suffered other wounds.[43]

While its contributions to Allied victory were great, World War I had revealed many army deficiencies in readiness for modern war. After studying requirements for an army able to meet America's needs, its leadership recommended a standing force of more than half a million men. A force of 280,000 was eventually authorized. Nothing like this number was ever funded, however, and by 1925 army strength stood at 137,000. (For comparison, note that France in 1925 had an active army of nearly 550,000, Italy of nearly 250,000, Japan of more than 230,000, and Britain one of more than 200,000.[44] Even defeated Germany, intended to be kept virtually disarmed and having no distant territories to garrison, was allowed an

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[42] Bureau of the Census, *Historical Statistics of the United States: Colonial Times to 1957: A Statistical Abstract Supplement,* Washington: Department of Commerce, 1960, Series Y 764, p. 736.

[43] *Ibid.,* Series Y 716, Y 724, Y 728, and Y 738-41, p. 735.

[44] League of Nations, *Armaments Year-Book: General and Statistical Information,* Geneva: League of Nations, 1926, pp. 131, 554, 652, and 720. Colonial troops and gendarmerie have been excluded from these totals, although the U.S. Army figures do include approximately 5,000 Philippine nationals who were enlisted in the army as Philippine Scouts.

army of 100,000.) Additionally there were 178,000 national guardsmen who got very limited training plus 97,000 reservists, almost all officers, who received virtually no training.

Given these realities, army leaders had to make choices which could only be based in their assessments of the threats to the nation's security and the ways in which they could best be met. In this, they could expect little help from the all but nonexistent national security policy apparatus of the U.S. government.[45]

The army had agreed with the navy that Japan was the source of the principal threat of a major conflict, and planned studiously for it.[46] But the service saw little it could usefully do to prepare for such a war, or to contribute to it if it occurred. Although the military effectiveness of the Japanese army was not reckoned to be particularly high, it seemed obvious that the forces that Japan could quickly and easily land in the Philippines would be able to overwhelm the American garrison of fewer than 20,000, together with any reinforcements that could be gotten there promptly. Occasionally there were spurts of hope, aspiration, or grim determination, but on the whole the Army's opinion was that no good could come to American forces in the islands in a war, and that after their fall the effort and glory of defeating Japan would rest largely with the naval services.[47] Thus the prospect of war with Japan was for the Army hopeless but not serious – not something it could usefully prepare for.

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[45] Ronald H. Spector, "The Military Effectiveness of the U.S. Armed Forces, 1919-1939," In *Military Effectiveness: Volume II, The Interwar Period,* edited by Allan R. Millett and Williamson Murray, Boston: Allen & Unwin, 1988, p. 79.

[46] Russell F. Weigley, "The Interwar Army," pp. 264-65; and William O. Odom, *After the Trenches: The Transformation of U.S. Army Doctrine, 1918-1939,* College Station, Texas: Texas A&M University Press, 1999, p. 186.

[47] Richard B. Meixsel, "Major General George Grunert, WPO-3, and the Philippine Army, 1940-1941," *Journal of Military History,* Vol. 59, No. 2 (Apr 1995), pp. 303-24; Edward S. Miller, *War Plan Orange,* pp. 53-59, 122-25; and Russell F. Weigley, "The Interwar Army," pp. 265-66.

The U.S. Army had fought in two great mass wars, the American Civil War and First World War, but both were regarded as exceptional. Most of its combat had been in a series of small wars against enemies ranging from native tribes to frontier irregulars to small states. These had all involved forces small relative to the dimensions of the theater involved, fighting over territory ill-served by roads and transportation. Thus the army was very conscious of needs for very mobile, maneuver-oriented forces. At the same time, experience in its two great wars combined with its emphasis on professional study of European experience and theory to impress the army with the need for concentrated power in major conflicts. The resulting tension in focus – between mobile light forces and forces capable of developing and sustaining combat power – dominated army thinking between the world wars.[48]

In principle, as laid down in the National Defense Act of 1920, the army was to have forces adequate to garrison overseas outposts and possessions in the Panama Canal Zone, Hawaii, the Philippines, and China as well as providing enough for eleven full-strength divisions at home ready for homeland defense or prompt deployment to trouble spots. A large and well-trained force of national guard and reserve divisions would be available to meet needs for a mass war.[49] All of this, of course, was stillborn owing to the refusal of Congress and Administration to provide the resources to carry it into practice.

Two understrength divisions were overseas, garrisoning the Philippines and Hawaii, together with two artillery regiments in the Panama Canal Zone.[50] Two half-strength divisions patrolled the Mexican border. After these needs were met, together with those of the army's basic overhead functions, remaining troop strength would

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[48] This is the interpretation, one I find generally convincing, of Russell F. Weigley as expressed in his "The Interwar Army," as well as "Shaping the American Army of World War II: Mobility versus Firepower," *Parameters*, Vol. 11, No. 2 (Sep 1981), pp. 13-21.

[49] Russell F. Weigley, "The Interwar Army," pp. 258-59.

[50] Mark Skinner Watson, *Chief of Staff: Prewar Plans and Preparations*, Washington: Center of Military History, U. S. Army, 1950, p. 148.

have been sufficient for one full-strength division, plus some additional units.[51] These men were in fact parceled out among nine division structures so that each had on average little more than battalion strength. Moreover, these skeletal units were spread across the nation, devoting most of their efforts to supporting and training the National Guard. Together with the lack of funds for transportation this meant that no one in the army, except for the overseas garrisons and frontier forces, received any training or field experience above the small-unit level.[52] Thus there was no possibility that the army could be prepared for wars whether small or large.

The army remained convinced of the great importance of moral factors, especially in light of its emphasis on infantry. "*War is the shock of two wills.... Moral force is the soul of battle,*" as one contemporary authority put it. But he went on to quote an unnamed Japanese observer of the First World War: "The most important factors of successful battle are the spirit of ardent attack and the support of mechanical power."[53] Ironically, the U.S. Army would ultimately place much more emphasis on a balance between the two factors than would the IJA.

The service studied its experience in France for lessons and revised its doctrine accordingly. Contrary to what might be expected, these did not focus on trench warfare or massive set-piece assaults after pulverizing artillery preparation. By the time the American Expeditionary Force got into the war (in mid 1918) the earlier pattern of static warfare was breaking down, helped in part of course by the arrival of millions of fresh troops from across the Atlantic. American officers believed that the experience of 1918 had discredited trench war and massive frontal assaults and vindicated American preference for "open warfare," involving vigorous and aggressive maneu-

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[51] William O. Odom, *After the Trenches*, pp. 92-93.

[52] Mark Skinner Watson, *Chief of Staff*, p. 149.

[53] Robert McCleave, "Infantry: Its Role, Capabilities, Limitations and Relation to Other Arms," *Infantry Journal*, Vol. 17, No. 5 (November 1920), pp 442-43.

ver by rifle-armed infantry. The war had taught the necessity for very close teamwork with strong artillery, however, as well the need for greater firepower within the infantry itself. With these amendments and with support from other arms the infantry could be expected to prevail on the battlefield of the future, the army believed. Such were the lessons of the war as the army saw them.[54]

Whether these were altogether the proper lessons to draw from the experience was open to some question.[55] Nevertheless, they were the lessons on which the army built its training and force development – such as they were – between the wars. They led to an emphasis on light, mobile formations, on infantry weapons, and on light support weapons that could keep up with the infantry using human or animal carriage or traction.

As is well known, the U.S. Army also remained devoted to the horse between the world wars. There were of course some entirely cultural reasons for this, but there also was a quite reasonable military argument. In America the cavalry had never been primarily a force for mounted combat, charging home with bared steel. Instead, the horse was a means for achieving mobility and the cavalry operated more as fast-moving infantry who dismounted to fight. For an army still expecting to fight frontier actions against irregular forces in a vast country much of which was as yet poorly provided with paved roads the horse continued to have an attraction as a mount or for drawing artillery and supply wagons. Thus the military horse faded more slowly from America's West than from Europe.[56]

At the opposite pole of military novelty, a number of new arms had come to prominence in the First World War, notably including chemical warfare, armor, and the airplane. Each produced enthusiasts who saw it as the future arbiter of battle. After the war tanks were subordinated to the infantry and kept in the background,

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[54] William O. Odom, *After the Trenches*, pp. 13-78.

[55] Russell F. Weigley, "Shaping the American Army," pp. 19-21.

[56] Russell F. Weigley, "Shaping the American Army," pp. 13-14.

chemical war gained a separate branch of its own but relatively minimal support, and military aviation prospered remarkably, if less rapidly and universally than its enthusiasts urged. As with the persistence of the horse (to which it was sometimes likened), the sudden rise of the airplane had both cultural and military motivations.

Senior officers of the army looked to its air forces to provide a major part of the service's combat power, and saw significant portions of the army's manpower and funds shifted to support it. Between 1925 and 1938, the air forces' share of army expenditure rose from 12% to 29%.[57] But most officers of the Air Corps felt themselves strangers in the army and shared a conviction that the air forces really should operate almost entirely separately from those on the ground. Aviation deserved more than a meager piece of hunger's pie as they saw it, and a great many of them envisioned its proper share as more on the order of 80% than 30% in any event. By selecting and precisely attacking the critical nodes in an enemy's industrial web, they believed, bombers could so cripple an opponent as to render all other operations of war largely secondary.

Japan's army: the IJA

Soldiers played a central role in Japanese society time out of mind but Japan's army in the modern sense dates only from the Meiji period.[58] It is worth bearing in mind that the leaders who took the

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[57] House of Representatives, *Military Establishment Appropriations for 1938: Hearings Before the Subcommittee of the Committee on Appropriations,* Washington: Government Printing Office, 1938, p. 484.

[58] A compact but remarkably comprehensive and insightful survey is Edward J. Drea, "The Imperial Japanese Army (1868-1945): Origins, Evolution, Legacy," in *War in the Modern World,* edited by Jeremy Black. [Forthcoming.] A good brief survey is Alvin D. Coox, "National Security and Military Command: The Japanese Army Experience," in *New Dimensions in Military History: An Anthology,* edited by Russell F. Weigley, San Rafael, California: Presidio Press, 1975. Leonard A. Humphreys, "The Japanese Military Tradition," in *The Modern Japanese Military System,* edited by James H. Buck, Beverly Hills: Sage Publications, 1975, is a concise survey of the entire history of Japan's military institutions, focusing both on continuities and

army and nation into World War II all had grandfathers or even fathers who had spent their formative years in a largely feudal society, with all this implies in terms of cultural dislocation.

The army was for long simply known as the Japanese Army. In the early 1930s, however, as a political statement its leaders insisted that it was the *Imperial* Japanese Army, and it is generally referred to as the IJA today.[59]

The Meiji leaders viewed the army that they had created as a crucial source of state stability and strength, and assigned to it a central role in the nation's affairs.[60] Rather unexpectedly (and not at all in accordance with oligarchic expectations or desires) ambitious men seized upon the relatively weak institution of the Diet or parliament as a tool of power and developed a political culture rather along

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changes. For the army's formation and institutional development see Roger F. Hackett, "The Military: A. Japan," in *Political Modernization in Japan and Turkey*, edited by Robert E. Ward and Dankwart A. Rustow, Princeton: Princeton University Press, 1964. A valuable study of the army's institutional and social development at a crucial turn is provided by Leonard A. Humphreys, *The Way of the Heavenly Sword: The Japanese Army in the 1920s*, Stanford: Stanford University Press, 1995. In this connection see also Shin'ichi Kitaoka, "The Army as a Bureaucracy: Japanese Militarism Revisited," *Journal of Military History*, 57, No. 5 (Oct 1993), pp. 67-86. The works of Alvin D. Coox collectively reveal much of the army's development and thought in the 1930s, particularly his *Nomonhan: Japan Against Russia, 1939*, Stanford: Stanford University Press, 1985 and *Year of the Tiger*. Saburo Hayashi and Alvin D. Coox, *Kōgun: The Japanese Army in the Pacific War*, Quantico, Virginia: Marine Corps Association, 1959 is useful for the prewar period, as is Carl Boyd, "Japanese Military Effectiveness: The Interwar Period," in *Military Effectiveness: Volume II, The Interwar Period*, edited by Allan R. Millett and Williamson Murray, Boston: Allen & Unwin, 1988. Several revealing studies are included in Edward J. Drea, *In the Service of the Emperor: Essays on the Imperial Japanese Army*, Lincoln: University of Nebraska Press, 1998.

[59] Leonard A. Humphreys, *The Way of the Heavenly Sword*, p. 106.

[60] The navy's political position was formally symmetrical with that of the army, but in practice its influence was constrained in some respects because the army had a far more pervasive presence within Japanese society. See Leonard A. Humphreys, *The Way of the Heavenly Sword*, p. 185, first note.

Western lines.[61] Japan's party politicians were able to extend their authority rather remarkably through the 1920s. In so doing they largely surmounted the doubts and gained the approval of the revenant of the oligarchy, Prince Kinmochi Saionji, thus bolstering their legitimacy.

The rise of the parties, however, came ineluctably at army expense. Endeavoring to appeal to a broader constituency than the army, they diverted resources away from military control and tried to insist on a measure of army accountability to civil authority. They were aided in this by divisions between the army and navy. At least in part because the services were rivals not simply for budgets but for ultimate political power, their rivalry was embittered far beyond anything familiar to Americans.

By the 1930s, however, both services had a number of officers whose moral outrage at the spectacle of politicians in the seats of power transcended interservice divisions.[62] There is no evidence of any concerted plot, but like-minded officers (and numerous sympathetic civilians) contrived by a variety of legal and extra-legal means to undermine the authority of party politicians and assert that of their services. The influence of the services over the government was never absolute, but it was substantial. With it, naturally, went a larger share of the nation's resources for defense.

The resurgence of military power was in part both a result of and a stimulus to an important change in the outlook of the military. Incessant feudal struggles for power had fostered the development of a military ethos of hardihood and fierce determination, latterly known in Japan as *bushido,* the way of the warrior. This was of course parallel to feudal development in Europe and its code of chivalry,

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[61] There is a rich literature on Japan's political development. A good recent survey is Richard Sims, *Japanese Political History Since the Meiji Renovation, 1868-2000,* New York: Palgrave, 2001.

[62] Leonard A. Humphreys, *The Way of the Heavenly Sword* summarizes these developments with respect to the army and provides a guide to other literature.

but persisted rather longer due to the somewhat later development of modernity in Japan. During the great peace of the Tokugawa Shogunate the military ethos was elaborated and codified. Indeed, no one seems to have felt the need for an explicit and named code of behavior until then.[63] This again represented a parallel with Europe; as there, the refined code of conduct for the warrior aristocracy provided a foundation of ostensible virtue for continuation of its rule after the civil unrest that provided its original *raison d'être* had been quelled.

Revival of conflict in the course of the Meiji revolution that ended the Shogunate and the subsequent establishment of the army naturally led to a conscious revival and remolding of military traditions.[64] These were, however, strongly overlaid with European military norms. During the Russo-Japanese War, European and Western observers were surprised and impressed by how close to Western norms the behavior of Japanese forces was. At the same time, the romantic fictions of the samurai code held great appeal for many foreigners as well as some (but not all) of Japanese society.[65] No Japanese Cervantes could ride out to prick the inflated bag of *bushido* while the government continued to pump it up to lift its authority and military strength.

The conflict with Russia was nevertheless a desperate one for Japan and particularly for its army, which suffered very severe casualties in what amounted to a foretaste of World War I. Officers dreaming of imperial destiny in Northeast Asia had to face the question of what would happen should their pursuit of it bring a conflict with an enemy stronger and more determined than the decayed Romanov empire. How could Japan, with its still weakly developed economy

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[63] Karl F. Friday, "Bushido or Bull? A Medieval Historian's Perspective on the Imperial Army and the Japanese Warrior Tradition," *History Teacher.* Vol. 27, No. 4 (May 1994), p. 340.

[64] Edward J. Drea, "The Imperial Japanese Army," p. 77.

[65] Nakao Shimazu, "The Myth of the 'Patriotic Soldier': Japanese Attitudes towards Death in the Russo-Japanese War," *War and Society,* Vol. 19, No. 2 (Oct 2001): pp. 69-89.

and scarcity of natural resources prevail in a modern war with a major power? The point was sharpened by observation of the mechanized carnage of World War I's Western Front.

Broadly speaking, two main schools of thought emerged. One group of officers looked primarily to modernization, of strengthening Japan economically to the point at which it could compete on equal terms with rich powers, and counseled accommodation in the meantime.[66] Others sought military salvation primarily in a quasi-religious "fundamentalist" revival (actually a thoroughgoing reinvention) of *bushido,* believing that illimitable offensive vigor could carry Japanese forces to victory over odds of ten to one or more.[67] A synthesis ultimately emerged, but one heavily weighted toward the fundamentalist view.

The fundamentalism was not exclusive and did not entirely divert the army from pursuing modernization of its equipment and forces. Yet army doctrine stressed infantry attacks with relatively light support by artillery pushed well forward, armor, and aviation.[68] In this it was curiously like the U.S. Army's doctrine – one student judges that no other army came as close to the U.S. doctrinally.[69] But the IJA differed in its lesser emphasis on supporting fires, particularly artillery indirect and counterbattery fires.

In a mirror of the situation on the other side of the Pacific, the IJA agreed with the IJN in principle that war with the United States was relatively likely. But like its American counterpart it viewed the prospect of a transpacific war without enthusiasm. Its real destiny, as it saw it (and it brooked no interference in such matters from civil authorities) lay on the Asian Continent with protection and/or ex-

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[66] Michael A. Barnhart, *Japan Prepares for Total War: The Search for Economic Security, 1919-1941,* Ithaca: Cornell University Press, 1987; and Humphreys, *The Way of the Heavenly Sword,* pp. 79-104.

[67] Karl F. Friday, "Bushido or Bull?" pp. 339-349; and Leonard A. Humphreys, *The Way of the Heavenly Sword, passim.*

[68] Edward J. Drea, "The Imperial Japanese Army," pp. 83-90.

[69] William O. Odom, *After the Trenches,* p. 186.

pansion of Japan's imperial frontier. As the Soviet Union gained economic and military strength in the 1930s, IJA attention turned toward it. China was not seen as presenting a significant military problem and the army's inability to put an end to Chinese resistance in the war that started in 1937 came as a distinct shock.

Even though the IJA's budget was far larger as a fraction of national income, it like the U.S. Army struggled with resource limitations. Nevertheless, it managed to keep higher troop levels and to invest more in new equipment.[70]

As in Europe, mounted troops enjoyed social prestige in feudal Japan. But at Nagashino in 1575 foot soldiers equipped with newly-introduced European matchlock firearms dealt a decisive defeat to the flower of Japanese chivalry.[71] While the European-style Japanese army incorporated cavalry on European lines, the infantry remained dominant. Like the U.S. Army, the Japanese retained some cavalry up to World War II, reflecting the relatively open and roadless terrain they expected to fight over in Northeast Asia.

The main importance of the horse was as a draft animal, however. Animal traction remained the norm for much of Japanese artillery and logistics throughout World War II (as it did also for the German army as well, of course). Again, this made some sense in Northeast Asia, but it would prove a serious handicap in the South Pacific and Southeast Asia, where the climate and terrain were poorly suited to horses.

The Japanese took up the airplane with only slightly less enthusiasm than the Americans and the army soon provided itself with air forces.[72] Japanese army aviators did not press strongly for organiza-

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[70] William D. O'Neil, *Interwar U.S. and Japanese National Product and Defense Expenditure.*

[71] This is the battle which forms the dramatic climax of Akira Kurosawa's film epic *Kagemusha,* testimony to its mythic significance.

[72] Aside from enthusiast publications regarding aircraft, markings, aces, etc., literature on the IJA's air arm is meager. See Alvin D. Coox, "The Rise and Fall of the Imperial Japanese Air Forces," in *Air Power and Warfare,* ed-

tional or doctrinal independence on British and American lines, however, and concentrated on tactical missions more akin to those of the German *Luftwaffe.*

Seeking to transform

A key issue for this study, obviously, is whether and to what extent the Japanese and American services consciously and deliberately endeavored to transform. Did they seek transformation in an effort to gain advantage in the prospective conflict between the U.S. and Japan? How did they formulate transformational strategies? What were the overall strengths and weaknesses of their transformation efforts?

Technology and transformation

It was during the nineteenth century that technological progress came to be widely recognized as a force in human history. Many resisted this realization, and military and to a lesser extent naval men were prominent among them. But in the wake of the First World War it became more difficult to deny the importance of technology in war. Thus perceptions of overall technical progress and recognition of specific technological opportunities became one impetus toward transformation. This was particularly so in the United States, where a sense of technological momentum and national techno-

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ited by Alfred F. Hurley and Robert C. Ehrhart, Washington: Office of Air Force History, 1979; Gerhard Krebs, "The Japanese Air Forces," in *The Conduct of the Air War in the Second World War: An International Comparison,* edited by Horst Boog, New York: Berg, 1992; and Eiichiro Sekigawa, *Pictorial History of Japanese Military Aviation.* For the war years, Military Analysis Division, *Japanese Air Power,* Washington: United States Strategic Bombing Survey (Pacific), July 1946 is useful. In all cases the naval air forces are treated as well as those of the army.

logical leadership became integral in the American self perception.[73]

Technological momentum of course exerted a particularly strong effect in aviation, motor vehicles, and radio, the most visible and talked-about technologies of their day. In the 1930s, all were areas of notable American strength. Japan had already developed a tradition of engineering excellence, but the nation's economy was not well enough developed to support technological industry on anything approaching the U.S. scale. The Japanese military services fostered domestic development of an aircraft industry in response to perceptions of the growing importance of aircraft in war. The IJA looked somewhat wistfully at America's floods of cars and trucks, one of the wonders of the day, but realistically concluded that a major motor-vehicle industry was beyond Japan's reach at that time. Plans to improve communications equipment were forestalled, along with other innovations, by the demands of the China Incident.

Naval transformation

There was much symmetry between the navies and their views. Each envisioned the coming conflict as climaxing in a decisive battle between fleets. The IJN counted on victory in it to consolidate its control over the Western Pacific and discourage the U.S. from further attempts to intrude in Japan's sphere. For the USN, defeat of the IJN was to clear the way for an effective blockade that would compel resource-poor Japan to come to terms.

We now know of course that the USN was to inflict major defeats on the IJN in not one but three great battles: Midway, the Philippine Sea, and the complex of actions surrounding the Leyte landings.

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[73] See e.g. C[lifford] C. Furnas, *America's Tomorrow: An Informal Excursion Into the Era of the Two-Hour Working Day,* New York: Funk & Wagnalls Company, 1932, a popular book at the time, and *idem, The Next Hundred Years: The Unfinished Business of Science,* New York: Reynal & Hitchcock, 1936, a main selection of the Book-of-the-Month Club.

These, together with a number of lesser combats, played a vital part in facilitating a wide variety of actions to bring the war to Japan, ranging from blockade to bombing to threat of invasion. If the IJN had been decisively victorious in any of the major battles it would have gravely impaired American offensive capabilities. To this extent, we can say that the naval transformation efforts were well conceived.

It is fair also to say that if the importance of carrier aviation was not fully appreciated, it did play a very important role in the pre-war thinking of both navies and increasingly so as aircraft capabilities improved.

At the same time, both navies failed significantly in envisioning the mode, methods, and context of naval war. Gun action between battleships, expected to be the ultimate arbiter, in the event played only a very small part. A great many kinds of naval actions other than main fleet battles played crucial roles, far beyond the mere skirmishing that had been widely anticipated. Many naval forces found their greatest importance in roles for which they had not originally been envisioned. Naval warfare took on strategic meaning and importance almost exclusively in a context of joint land-air-sea operations. And land and air operations were themselves crucially important to naval operations.

Army transformation

While there was less similarity in the situations of the two armies, there was a certain symmetry, at least in a negative sense. Neither thought very much about fighting the other, even though they both accepted the likelihood of a war between their two nations. In effect, both expected the war between the U.S. and Japan to be largely a naval affair in which army energies would be directed largely elsewhere. They anticipated meeting only in the Philippines, and neither devoted great effort to preparing even for that conflict.

Where the navies viewed each other with a certain wary respect based in an appreciation for the quantity and quality of its ships,

neither army entertained a very high opinion of the other. The U.S. Army did study its Japanese counterpart and saw many similarities and much to admire in the quality of its troops but concluded that on the whole it was second-rate, citing the IJA's relative lack of mechanization and firepower, dependence on manpower, inadequate staff planning, and over-reliance on night operations, surprise, and close combat.[74] The Japanese army did not even study its U.S. counterpart.[75] This, however, did not mean that Japanese officers had no views on U.S. Army capabilities: Americans were regarded as so corrupted by liberal individualism as to deprive them of the toughness and determination necessary for effective fighting.[76] Even the few IJA officers who had observed the peacetime U.S. Army at close hand were generally unimpressed.[77] Thus each army thought it saw in the other a deficiency in the qualities it believed most important in war.

In effect the IJA turned its back toward America, and the U.S. Army reciprocated. The Soviet Union was the great obsession of the Japanese Army. The U.S. Army in the 1920s and 1930s could not afford to speak in public of overseas action, regardless of circumstance, but it measured itself against European armies.

While the IJA and U.S. Army did not seek to transform to meet one another, however, they did seek to transform. In so doing both achieved significant capability improvements. At the same time, nei-

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[74] Thomas G. Mahnken, *Uncovering the Ways of War: U.S. Intelligence and Foreign Military Innovation, 1918-1941*, Ithaca: Cornell University Press, 2002, pp. 48-49 and William O. Odom, *After the Trenches*, pp. 186-189.

[75] Michael A. Barnhart, "Japanese Intelligence Before the Second World War," p. 446; Edward J. Drea, *In the Service of the Emperor*, pp. 27, 64, and 69; and Saburo Hayashi and Alvin D. Coox, *Kōgun*, pp. 18 and 23.

[76] Alvin D. Coox, "Flawed Perception And Its Effect Upon Operational Thinking," pp. 245-252, and Edward J. Drea, *In the Service of the Emperor*, p. 32.

[77] Alvin D. Coox, "Flawed Perception And Its Effect Upon Operational Thinking," pp. 246-47 and 250.

ther did an adequate job of preparing forces to fight the war to come.

Objects of transformation

Having seen that each of the services in Japan and the United States sought transformation, how did they select what and how to transform? What were the roles of strategic objectives, preexisting doctrinal concepts, technological opportunities, economic calculation, external political pressures and objectives, and personal and group enthusiasms?

In this section I treat transformation efforts as they initially evolved after World War I, generally up to the late 1930s, with a later section devoted to examination of how transformation was itself transformed in response to experience and feedback.

Japanese Navy

The climactic decisive battle was a major focus of naval interest almost everywhere before World War II, but for the IJN it amounted to an *idée fixe* – not only the beginning but the end of the thinking of those who dominated the service's policies.[78] They convinced themselves that in order to be able to prevail in a battle against an American fleet approaching Japan's waters the IJN needed to have at least 70% of American strength in battleships and other key ship types and to be generally superior in quality.[79] The logic behind this was anything but airtight, but inevitably the political demands for a

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[78] David C. Evans and Mark R. Peattie, *Kaigun, passim;* Saburo Toyama, "Lessons From the Past," United States Naval Institute, *Proceedings*, Vol. 108 (Sep 1982), pp. 62-69; and Toshiyuki Yokoi, "Thoughts on Japan's Naval Defeat," in *The Japanese Navy in World War II: In the Words of Former Japanese Naval Officers*, edited by David C. Evans and Raymond O'Connor, Annapolis: Naval Institute Press, 1986.

[79] David C. Evans and Mark R. Peattie, *Kaigun*, pp. 143-144.

solid front in dealing with domestic and foreign rivals froze it into an unquestionable dogma.

Because superiority in quality was a part of the formula, the IJN pursued transformation initiatives aimed at outdistancing the USN and other possible foes in the quality of ships, weapons, and personnel. All of these were focused on the presumed decisive battle.

As Japan's economy was only about 15% as large as that of the United States in this era,[80] the IJN's ability to maintain a strength equal to 70% of the USN's depended on American restraint as well as Japanese national determination. But the confrontational policies pursued by Japan in the 1930s did nothing to encourage this necessary restraint. The situation was not helped when key elements in the IJN leadership demanded not 70% of American strength but parity, calling it a matter of national honor as well as security. As it became clear that parity and even a 70% ratio would be unattainable, the IJN turned even more strongly toward quality as the balancer, and put added energy into transformation.

There is no indication that the IJN ever reexamined its commitment to the decisive battle. They would fight and win the decisive battle, sending the invading U.S. fleet to the bottom, and that would be it: the war would be over. The only other operations of war that the IJN showed any significant interest in were defense of insular bases in the Central Pacific and strategic bombardment of targets deep in China.

The IJN's tactics for the decisive battle, deriving from its Russo-Japanese War experiences, called for a series of attacks to whittle down the strength of the approaching U.S. fleet before the final confrontation between lines of battleships. Submarines would keep watch on the USN's fleet bases and then trail and report on the fleet as it sailed westward. Other subs would be guided into position to attack the fleet, using high speed to leapfrog ahead and make re-

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[80] William D. O'Neil, *Interwar U.S. and Japanese National Product and Defense Expenditure.*

peat attacks. Long-ranged island-based bombers, escorted by long-range fighters, would deliver torpedo and bombing strikes.

As the Americans approached Japanese waters they would be met at night by mixed forces of cruisers and destroyers. After the powerful cruisers had breached the outer U.S. screen, they and the lighter ships would pour through to deliver massive torpedo attacks. (Later, as the USN built more powerful cruisers of its own, battleships were added to strengthen the night attack force.)

As the dawn overtook the surviving American units they would encounter the main Japanese force, whose outriders would envelop the invaders and deliver further torpedo attacks along with carrier aircraft. Then the Japanese battleships would approach, using superior speed and armament to engage the Americans at ranges beyond those at which they could make any effective reply. Finally, aircraft and light forces would hunt down any survivors.

The details varied from time to time, but this gives a picture of the general pattern. To implement this doctrine, the IJN pressed a variety of developments.[81]

- **Submarines.** Large, fast subs of several specialized types were developed for particular missions. Miniature subs with two-man crews were to provide a sort of deployable minefield, to be deployed in advance along the track of the American fleet. Another type virtually unique to Japan was the large long-range submarine carrying a floatplane for reconnaissance. Like other nations, Japan spent several years after World War I digesting the lessons of German submarine technology. Thereafter, IJN submarines were domestically designed and produced. The emphasis in design was generally on range and

[81] David C. Evans and Mark R. Peattie, *Kaigun,* is the basic reference for what follows. It will be cited simply as *Kaigun* in giving page citations.

on speed to permit getting ahead of the American fleet, at the expense of hull strength and diving times.[82]

- **Land-based bombers.** Its powerful land-based air striking force was a unique feature of the IJN. Japan's aircraft industry, with very limited domestic and export commercial markets, was built largely through military initiative. By the mid 1930s, it was producing aircraft to equal the best of other nations. In the 1930s the IJN concluded that long-range aircraft based on Central Pacific islands could deliver heavy bombing and torpedo attacks against a U.S. fleet advancing across the ocean, inflicting serious attrition. To fulfill this vision it produced a bomber having high speed, a good bomb load, and outstanding range: the Mitsubishi G3M (first flight July 1935).[83]

- **Carrier aviation.** While carrier aviation did not occupy a central place in the thinking of most of the IJN's chiefs, its importance was acknowledged and its development pressed. As relatively limited information on carrier design and operations was available from foreign sources, the navy pressed ahead with its own development and experimentation, and by the mid 1930s had reached a good understanding of the practical demands. With the maturation of the nation's aircraft industry it was able to obtain carrier aircraft of generally high quality. The navy's first cantilever-wing monoplane fighter to see service, the Mitsubishi A5M, first flew early in 1935 and entered service in 1937. It retained the older fixed (but streamlined) landing gear and open cockpit and used engines of 600 to 700 horsepower, but had outstanding performance for its time. As in

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[82] *Kaigun,* pp. 212-219, 272-273, and 428-434; Carl Boyd and Akihito Yoshida, *The Japanese Submarine Force and World War II,* Annapolis: Naval Institute Press, 1995, pp. 1-25; and U. S. Naval Technical Mission to Japan, *Characteristics of Japanese Naval Vessels: Article 1, Submarines.* S-01-1, Washington: Department of the Navy, Jan 1946.

[83] *Kaigun,* pp. 299-340; René J. Francillon, *Japanese Aircraft of the Pacific War,* Annapolis: Naval Institute Press, 1988, pp. 1-28 and 350-357; and Mark R. Peattie, *Sunburst, passim.*

other branches of the navy (and army), great stress was laid on rigorous training and development of tactical doctrine.[84]

- **Flotilla forces.** The IJN developed new types of especially powerful cruisers and destroyers whose principal striking arm was the torpedo, although they also carried strong gun armament. These were substantially larger than U.S. and other ships of similar types, in violation of Japan's obligations under the Five Power (Washington) and London Treaties.[85]

- **Battleships.** Japan was blocked from building new battleships[86] by the naval arms treaties until it denounced them in December, 1934, with final effect from the end of 1936. In the meantime, the IJN began a program of very thorough (and costly) reconstruction of its older battleships, increasing power and speed, adding more armor, and improving the effectiveness of the main armament. Plans were prepared, in great secrecy, for "super-battleships" with half again the tonnage of any previous such ship (and nearly twice as large as permitted under the treaties), with correspondingly strong armor and armament. The first of these, *Yamato,* was laid down in 1937. The IJN expected that ships of this type would be able to engage and destroy U.S. battleships beyond the range at which they could effectively reply.[87]

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[84] *Kaigun,* pp. 299-340; René J. Francillon, *Japanese Aircraft of the Pacific War,* pp. 268-482, *passim*; and Mark R. Peattie, *Sunburst, passim.*

[85] Roger Chesneau, editor, *Conway's All the World's Fighting Ships, 1922-1946,* London: Conway Maritime Press, 1980 and Annapolis: Naval Institute Press, 1984, pp. 186-194; *Kaigun,* pp. 199-298; and Eric Lacroix and Linton Wells, II, *Japanese Cruisers of the Pacific War,* Annapolis: Naval Institute Press, 1997. It is not clear that this violation of the treaties was in fact a deliberate and calculated policy, but certainly conformity with the treaties did not have the same priority that it held in America and Britain.

[86] Specifically, the prohibition extended to "capital ships" of more than 10,000 tons or armed with guns of more than 8 inches caliber.

[87] Roger Chesneau, editor, *Conway's All the World's Fighting Ships, 1922-1946,* pp. 171-173 and 178; W[illiam] David Dickson, "*Yamato.*" *Warship International,* No. 4 (1975), pp. 294-318; and *Kaigun,* pp. 199-298 and 370-377

- **Torpedoes.** The IJN placed great emphasis on the torpedo as the only weapon with which its submarines, long-range bombers, cruisers, and destroyers could sink battleships. Japanese torpedoes in general were well designed, well made, and quite efficient. Extra-large torpedoes were developed for use by cruisers and destroyers in which compressed air was replaced by compressed pure oxygen for much longer range at high speed, with little wake. This represented a significant technical accomplishment, not duplicated elsewhere, in overcoming the explosion hazards associated with pure oxygen. With ranges exceeding 10 miles – far greater than any other torpedo – and fired in great shoals, oxygen torpedoes were counted upon to achieve dozens of hits on American ships, each crippling due to the heavy warhead.[88]

- **Night combat.** All navies were aware of the importance of night combat in principle, but the IJN pursued it with a determination not matched elsewhere. Cruisers and destroyers were provided with plentiful top-quality optical equipment for night search and targeting, manufactured by an industry which the navy had created for the purpose.[89] More importantly, ships trained and practiced relentlessly in night attacks, accepting considerable risk of collision. The night tactical doctrine

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[88] John F. De Virgilio, "Japanese Thunderfish," *Naval History*, Vol. 5, No. 4 (Winter 1991), pp. 61-8; *Kaigun*, pp. 266-272; Jiro Itani, Hans Lengerer and Tomoko Rehm-Takahara, "Japanese Oxygen Torpedoes and Fire Control Systems," in *Warship, 1991*, edited by Robert Gardiner, London: Conway Maritime Press, 1991; Frederick J. Milford, "Imperial Japanese Navy Torpedoes, Part II: Heavyweight Torpedoes, 1918-1945," *Submarine Review*, (Jul 2002), pp. 51-66; U. S. Naval Technical Mission to Japan, *Japanese Torpedoes and Tubes: Article 1, Ship and Kaiten Torpedoes*, O-01-1, Washington: Department of the Navy, Apr 1946; and *idem, Japanese Torpedoes and Tubes: Article 2, Aircraft Torpedoes*, O-01-2, Washington: Department of the Navy, Mar 1946.

[89] Jeff Alexander, "Nikon and the Sponsorship of Japan's Optical Industry by the Imperial Japanese Navy, 1917-1945," *Gateway*. (Winter 2001).

stressed the need for all ships to work together in pressing the attack.[90]

- **Communications intelligence.** The IJN had been practicing communications intelligence (COMINT) since the Russo-Japanese War. Following World War I, the United States became its principal target, including diplomatic as well as naval communications. American crypto systems at this time were very simple. Through a combination of purely cryptanalytical solutions aided by various cribs together with photocopies of code books and key material obtained from clandestine raids on diplomatic premises, Japanese naval codebreakers were able to read much American naval and diplomatic traffic throughout the 1930s. Intercept teams deployed aboard inconspicuous ships shadowing task forces eavesdropped on many manor USN exercises. And the IJN developed advanced and effective high-frequency radio direction finding (HFDF) systems enabling them both to intercept communications and track transmitters from island stations. From these sources much was learned about USN operations, capabilities, and systems. How effectively this information was used is hard to judge; it is certainly clear that in general IJN intelligence analysis and communication with higher commanders was not very good.[91]

In addition, in the early 1930s the IJN played a major role in transforming Japan's aircraft industry by its insistence on buying aircraft

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[90] *Kaigun,* pp. 220-232 and 273-281.

[91] Michael A. Barnhart, "Japanese Intelligence Before the Second World War"; Edward J. Drea, "Reading Each Other's Mail: Japanese Communication Intelligence, 1920-1941," *The Journal of Military History.* 55, (Apr 1991), 185-205; *Kaigun,* pp. 415-423; Yasuzo Nakagawa, *Japanese Radar and Related Weapons of World War II,* Laguna Hills, California: Aegean Park Press, 1997, pp. 19-20; and Toshiyuki Yokoi, "The Japanese Version of the Black Chamber: The Story of the Naval Secret Chamber," Allied Translator and Interpreter Section, Military History Section, Headquarters, Army Forces Far East, Doc. No. 64718, 31 Jan 1951.

of domestic design and manufacture, thus moving to break its dependence on foreign sources.[92]

There are several areas in which the *absence* of IJN transformation effort should be noted:

- **Radar.** Japan unquestionably had the scientific and technical capacity to develop radar on approximately the same timescale as the U.S. and Britain, but failed to exercise it effectively. Engineers in Japan were generally aware of the possibility of radar development and had hints of American and British activity in the field, but the first very tentative step – an interference experiment – was not taken until 1936, in an experiment duplicating what had been done in the U.S. before 1930. In the late 1930s Japanese engineers led the world in development of cavity magnetrons for generation of microwaves and the reflection experiments were quickly repeated at microwave frequencies. Not until a Japanese delegation visited Germany early in 1941, however, did any serious interest in radar as such emerge. The navy allocated a large sum (¥11 million) for radar work and two experimental pulse radars were demonstrated in the months immediately before Pearl Harbor, one at microwave frequencies.[93]

- **Antisubmarine warfare.** Between the world wars, all navies turned their backs on the lessons of the desperate struggle to overcome the U-boat threat in 1916-1917, but none more so nor with more disastrous consequences than the IJN. Hydrophone listening equipment was developed and fairly widely fitted, along with limited numbers of simple active sonars. That

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[92] *Kaigun*, p. 28.

[93] Yasuzo Nakagawa, *Japanese Radar and Related Weapons*, pp. 1-31; S[higeru] Nakajima, "The History of Japanese Radar Development to 1945," in *Radar Development to 1945*, edited by Russell W. Burns, London: Peter Peregrinus & Institution of Electrical Engineers, 1988, pp. 241-49; Roger I. Wilkinson, "Short Survey of Japanese Radar—I," *Electrical Engineering*, Vol. 65 (Aug-Sep 1946), pp. 370-7; and *idem*, "Short Survey of Japanese Radar—II," *Electrical Engineering*, Vol. 65 (Oct 1946), pp. 455-63.

seems to have been the extent of IJN ASW effort until well into the war.[94]

U.S. Navy

The USN also looked forward to a decisive battle, but saw it as one element in an extended campaign. Before there could be a great battle in the West Pacific, the fleet had to make its way there. The idea of simply charging across the ocean with no immediate support, in the manner of Rozhdestvenski's unfortunate Russians, was dropped very early on. The fleet needed to have a good base not too far from the scene of the action. The more closely the USN examined the situation the more elaborate an effort this seemed to entail, and the longer the time it seemed likely to require. Then, following the defeat of the IJN in decisive battle, the navy would settle down to strangling Japan with blockade. Thus the USN had a relatively comprehensive operational plan.

Many elements of this plan were recognized to call for novel capabilities. Nevertheless, the navy's transformation efforts focused in practice principally on preparations for the decisive battle, with relatively limited attention paid to the other prerequisites.

USN transformation efforts in support of the decisive battle seem to have been at once broader and more flexible but less thorough or painstaking than those of the IJN. Major efforts included:

- **Airships.** Much time and effort was devoted to development of large rigid Zeppelin-type airships for scouting. In the 1920s, when airplane performance was limited and did not appear to be progressing rapidly, the case for the airship seemed to have some merit. Increasing airplane performance combined with better understanding of the airship's technical limitations to make the case much weaker by the early 1930s, but the leaders of the navy's aeronautical community persisted with the big

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[94] *Kaigun,* pp. 434-441; and U. S. Naval Technical Mission to Japan, *Japanese Sonar and Asdic,* E-10, Washington: Department of the Navy, Dec 1945.

ships until a series of disasters starkly revealed the type's defects. Congressional and Presidential opposition forced the navy to drop the program entirely.[95]

- **Seaplanes.** The great advances in aeronautical technology of the 1930s at first seemed to be particularly beneficial to seaplanes, which could dispense with the weight and complication of retractable landing gear. A number of flying boat types found commercial success as airliners. The navy developed enthusiasm for large seaplanes for scouting – and in some quarters for bombing. With ships to act as seaplane tenders they appeared to offer a reconnaissance and perhaps striking force that the fleet could take with it as it crossed the Pacific, operating from any sheltered stretch of water. The streamlined monoplane twin-engined Consolidated PBY Catalina flying boat, which first flew in 1935, represented the first embodiment of the navy's hopes for seaplanes.[96]

- **Aircraft carriers.** While the USN numbered both a few impractical visionaries and a sufficiency of blinkered conservatives among its senior ranks, it was fortunate in having respected senior officers who simply sought to maximize its sea power and saw the carrier-based airplane as a tool that could help. Airplanes of the 1920s lacked the performance to deliver effective attacks against heavy ships, but could perform vital service in expanding the fleet's range of vision for reconnaissance and for correcting the fall of shot of battleship guns. Control of the air over the battle area could enable fleet aircraft to perform

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[95] Douglas H. Robinson and Charles L. Keller, *"Up Ship!": A History of the U.S. Navy's Rigid Airships, 1919-1935*, Annapolis: Naval Institute Press, 1982, pp. 193-195; and Richard K. Smith, *The Airships Akron & Macon: Flying Aircraft Carriers Of The United States Navy*, Annapolis: Naval Institute Press, 1965, pp. xix-xxii and *passim*.

[96] Thomas C. Hone, Norman Friedman and Mark D. Mandeles, *American & British Aircraft Carrier Development, 1919-1941*, pp. 59-60; Edward S. Miller, *War Plan Orange*, pp. 175-179; and Ray Wagner, *American Combat Planes*, 3rd, enlarged edition, Garden City, New York: Doubleday & Co., 1982, pp. 303-313.

these functions while denying them to the enemy, thus giving the USN a battle-winning advantage. So the navy pursued development of carriers that could put strong forces in the air, first to combat enemy aircraft and then, as capabilities improved, to destroy enemy carriers.[97]

- **Carrier aircraft.** Commercial markets played a much larger role in the development of the aircraft and engine industries in the U.S. than in Japan. Nevertheless, the military market was extremely important, and the services bore the primary responsibility for stimulating development of high-powered engines. Airplane capabilities improved only modestly through the 1920s. But in the 1930s designers were able to combine growing knowledge of the sciences critical to flight with improving engineering technique to produce dramatic gains. The most dramatic developments occurred in America and were particularly marked in multi-engine civil transport aircraft. There was a period of uncertainty about whether and how these gains might be applied to carrier aircraft. Thus there was a lag of more than four years between the introduction of the first "modern" airliner (Boeing 247, whose first revenue flight was in June, 1933) and the appearance of the first comparable monoplane aircraft on USN carrier decks (Douglas TBD, entering squadron service in October, 1937). Only in the 1939-40 period did carriers start to have aircraft with the speed, range, and weapons load to pose a serious

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[97] The literature on interwar development of carrier aviation in the USN is particularly extensive. The following three recent works build upon and provide a guide to earlier work concerning ideas and doctrine: Mark Allen Campbell, "The Influence of Air Power Upon the Evolution of Battle Doctrine in the U.S. Navy, 1922-1941," Master's thesis, University of Massachusetts, Boston, 1992; Thomas C. Hone, Norman Friedman and Mark D. Mandeles, *American & British Aircraft Carrier Development, 1919-1941* (especially, in this connection, pp. 1-82); and Thomas Wildenberg, "In Support of the Battle Line: Gunnery's Influence on the Development of Carrier Aviation in the U.S. Navy," *Journal of Military History*, Vol. 65, No. 3 (Jul 2001), pp. 697-712. For details on the ships and analysis of their characteristics and designs, see Norman Friedman, *U.S. Aircraft Carriers: An Illustrated Design History*, Annapolis: Naval Institute Press, 1983, pp. 7-117.

threat to heavy ships or major land targets, and this capability was not operationally developed and proven until 1941. It is important to recognize this to understand the Navy's response to the rise of carrier aviation.[98]

- **Submarines.** Like its Japanese counterpart, the USN studied German submarine technology following World War I and incorporated it into its own developments. The fleet sought a "fleet sub" that could operate far in the van of the advancing battle force as a scout and first line of defense. It slowly became apparent to the constructors that this was not an attainable goal in technical terms, and to submariners that it was not an operationally-feasible method of operation in any event. Technical development of a large transoceanic submarine type nevertheless proceeded under the rubric of the *fleet submarine.* The technical challenges were formidable, and particularly in regard to developing a suitable domestic Diesel engine. The engine problem was eventually solved in part through informal alliances with manufacturers seeking support in developing engines suitable for Diesel locomotives.[99]

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[98] Philip Jarrett, editor, *Biplane to Monoplane: Aircraft Development, 1919-39,* Putnam's History of Aircraft, London: Putnam Aeronautical Books, 1997; Laurence K. Lofton, Jr. *Quest for Performance: The Evolution of Modern Aircraft,* Washington: National Aeronautics and Space Administration, 1985, pp. 67-101; Ronald Miller and David Sawers, *The Technical Development of Modern Aviation,* New York: Praeger Publishers, 1970, pp. 9-23 and 47-97; Robert Schlaifer and S[amuel] D. Heron, *Development of Aircraft Engines and Fuels,* Cambridge: Graduate School of Business Administration, Harvard University, 1950, Elmsford, New York: Maxwell Reprint, 1970, pp. 159-198, 246-320, and 591-630; F. Robert van der Linden, *The Boeing 247: The First Modern Airliner,* Published for the National Air and Space Museum, Seattle: University of Washington Press, 1991, p. 75; and Ray Wagner, *American Combat Planes,* pp. 131-144, 322-333, and 346-378.

[99] John D. Alden, *The Fleet Submarine in the U.S. Navy: A Design and Construction History,* Annapolis: Naval Institute Press, 1979, pp. 8-75; Norman Friedman, *U.S. Submarines Through 1945: An Illustrated Design History,* Annapolis: Naval Institute Press, 1985, pp. 163-231 and 258-265; Gary E. Weir, *Building American Submarines, 1914-1940,* Washington: Naval Historical Center, 1991, *passim*; and Gary E. Weir, "The Search for an American

- **Battleships.** Most senior USN leaders continued to view the battleship as a key to sea power, although perhaps not the sole key. Steps were taken to upgrade older battleships. Nothing was done to increase their speed, which was very slow. Their armor also was mostly untouched, but that had been strong to begin with. Torpedo protection was strengthened. The effort at true transformation was concentrated on armament and gunnery, with the intention of destroying the enemy before he could close to ranges at which his own fire could be effective against the heavily armored American ships. Gun elevations were increased for longer range, aerial spotting and correction of the fall of shot practiced, and gyroscopically-stabilized electro-mechanical fire control systems perfected to automate accurate gun aiming. An advanced projectile was designed to optimize armor penetration at long ranges. An elaborate but flexible doctrine for battlefleet gunnery engagements was developed and rigorously practiced and tested in exercises. With the partial relaxation of treaty restrictions following Japan's withdrawal, the USN resumed battleship construction with ships that were distinctly faster than the older types and embodied many improvements, but were unable to match the protection and gun power of the much larger IJN superbattleships (whose characteristics were not learned until almost a decade later).[100]

- **Cruisers and destroyers.** The cruiser and destroyer were the U.S. fleet's maids of all work, particularly regarded for their

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Submarine Strategy and Design, 1916-1936," *Naval War College Review,* (Winter 1991), pp. 34-48.

[100] Roger Chesneau, editor, *Conway's All the World's Fighting Ships, 1922-1946,* pp. 90-92 and 97-98; A. Ben Clymer, "The Mechanical Analog Computers of Hannibal Ford and William Newell," *IEEE Annals of the History of Computing,* Vol. 15, No. 2 (1993), pp. 20-27; Trent Hone, "Building a Doctrine: USN Tactics and Battle Plans in the Interwar Period," *International Journal of Naval History,* (Oct 2002); W[illiam] J. Jurens, "The Evolution of Battleship Gunnery in the U,S, Navy, 1920-1945," *Warship International,* No. 3 (1991), pp. 240-71; and Robert F. Sumrall, *Iowa Class Battleships: Their Design, Weapons & Equipment,* Annapolis: Naval Institute Press, 1988, pp. 8-22.

contributions to informing, screening, and protecting the battle line and, as time went on, carriers. The cruiser of this era was a distinct type brought into existence by the naval armaments treaties which forbade building ships of more than 10,000 tons or guns of caliber greater than 8 inches. The USN failed to think in terms of torpedoes with the performance achieved by the IJN's large oxygen torpedoes and as a result concluded that the torpedo, although very dangerous should it hit a ship, was essentially a short-range weapon. Hence a strong gun armament, effective at longer ranges, was seen as the means to maximize cruiser fighting power. Destroyers were a different case, seen as too small to mount a gun armament effective at any but the shortest of ranges. The torpedo was thus their principal offensive weapon, but it was anticipated that it would be of more value as a threat forcing the enemy to turn away than as an actual sinker of heavy ships. Of course the USN was handicapped by its reasonably scrupulous adherence to treaty tonnage limitations; the less scrupulous IJN built ships that generally ran 20% to 30% larger than allowed, with corresponding advantages in armament and performance.[101]

- **Torpedoes.** These underwater weapons were critical to the submarines, destroyers, and torpedo planes armed with them. The Navy's torpedo development and production was concentrated at its Torpedo Station in Newport, Rhode Island, where new torpedoes were developed for aircraft (Mk. 13), submarines (Mk. 14) and destroyers (Mk. 15). All incorporated new technology, most notably a highly-secret magnetic influence

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[101] Andrade, Ernest, Jr., "Arms Limitation Agreements and the Evolution of Weaponry: The Case of the 'Treaty Cruiser'," in *Naval History: The Sixth Symposium of the U.S. Naval Academy*, edited by Daniel M. Masterson, Wilmington, Delaware: Scholarly Resources, 1987; Norman Friedman, *U.S. Cruisers: An Illustrated Design History*, Annapolis: Naval Institute Press, 1984, pp. 97-251; Norman Friedman, *U.S. Destroyers: An Illustrated Design History*, Annapolis: Naval Institute Press, 1982, pp. 75-109; and T. J. McKearney, "The Solomons Naval Campaign: A Paradigm for Surface Warships in Maritime Strategy," M.A. thesis, Naval Postgraduate School, Monterey, California, 1985, pp. 70-138.

exploder for the Mk. 14 and 15, intended to detonate the warhead in a ship's most vulnerable place, beneath its keel. This, it was believed, marked a major transformation, allowing the heaviest ships to be severely damaged or even destroyed with a single hit. But the Mk. 15, restricted to 21-inch diameter and relying on compressed air rather than oxygen, was slightly slower and much shorter ranged than the new Japanese destroyer torpedoes.[102]

- **Sonar.** The severe threat that German U-boats had posed to Britain and the U.S. during World War I had stimulated intensive research on a variety of possible countermeasures, including acoustic detection both by passive listening and active echo-ranging. Following the war the USN established the Naval Research Laboratory (NRL) which led its sonar development efforts between the wars. By the mid 1930s NRL had evolved a single-beam manually pointed "searchlight" sonar with electronic amplification and a magnetostrictive transducer, the QC, and installation on destroyers had begun. It was principally an attack system, having low probability of detection in search mode, but was not particularly well matched to the characteristics of the destroyer's sole weapon against submerged subs, the depth charge. Visual search by aircraft was seen as the primary mode of submarine detection.[103]

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[102] Robert Gannon, *Hellions of the Deep: The Development of American Torpedoes in World War II*, University Park, Pennsylvania: Pennsylvania University Press, 1996, pp. 77-82; Frederick J. Milford, "U.S. Navy Torpedoes, Part One: Torpedoes Through the Thirties," *The Submarine Review*, (April 1996).

[103] Norman Friedman, *U.S. Destroyers*, pp. 69-72; Norman Friedman, *U.S. Naval Weapons: Every Gun, Missile, Mine and Torpedo Used by the U.S. Navy from 1883 to the Present Day*, Annapolis: Naval Institute Press, 1982, pp. 122-23 and 134-35; Willem Hackmann, *Seek & Strike: Sonar, Anti-Submarine Warfare and the Royal Navy, 1914-54*, London: Her Majesty's Stationery Office, 1984, pp. 135-38, 172, and 199; Elias Klein, *Notes on Underwater Sound Research and Applications Before 1939*, ONR Report ACR-135, Washington: Office of Naval Research, Department of the Navy, 1967, pp. 18-36; Marvin Lasky, "A Historical Review of Underwater Acoustic Technology 1916-1939

- **Radar.** NRL was very active in radio research and its scientists soon recognized the potential for detection of ships and aircraft using reflected radio waves. Official encouragement was slow in coming but they persisted and pried approval for modest research from the Bureau of Engineering. The work was not forwarded by internecine conflicts over the control and mission of the laboratory within the Navy Department, nor by Depression funding cutbacks. Nor did radio detection command highest priority within NRL. Still the work crept forward. By the end of 1935, a second man had been assigned; the older was 32. Yet they completed a working pulse radar and by May of 1936 were able to demonstrate aircraft detections to ranges of 17 miles. Navy interest sharpened and the pace of work quickened. Early in 1939 an NRL prototype radar went to sea for tests aboard a battleship.[104]

- **Communications intelligence and security.** The story of USN COMINT parallels that of the IJN to a remarkable degree almost to the brink of war, with very similar methods, successes and failings. The U.S. was distinctly behind in HFDF and did

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with Emphasis on Undersea Warfare," *U.S. Navy Journal of Underwater Acoustics*, Vol. 24, No. 4 (Oct 1974), pp. 616-19; Office of Scientific Research and Development, National Defense Research Committee Division 6, *A Survey of Subsurface Warfare in World War II*, Summary Technical Report of Division 6, NDRC, Vol. 1, Washington, 1946, pp. 226-27; and Robert J. Urick, *Principles of Underwater Sound*, 3rd edition. New York: McGraw-Hill, 1983, pp. 4-6.

[104] The development of radar at NRL, in contrast to the sonar story, has been much written about. The institutional aspects are best treated by David Kite Allison, *New Eye for the Navy: The Origin of Radar at the Naval Research Laboratory*, Washington: Naval Research Laboratory, 1981. In addition to the works it cites, further technical detail may be found in L[inwood] S. Howeth, *History of Communications-Electronics in the United States Navy*, Washington: Government Printing Office, 1963, pp. 443-69; Robert M[orris] Page, "Early History of Radar in the US Navy," in *Radar Development to 1945*, edited by Russell W. Burns, London: Peter Peregrinus & Institution of Electrical Engineers, 1988; *idem, The Origin of Radar*, Garden City, New York: Anchor Books, Doubleday & Co., 1962; and S[ean] S. Swords, *Technical History of the Beginnings of RADAR*, London: Peter Peregrinus & Institution of Electrical Engineers, 1986, pp. 101-11.

not have an efficient set in service until it began deploying a shore-based unit employing a trainable Adcock array in 1938. One important departure, however, is that the USN COMINT organization was responsible for monitoring USN communications and assessing their security as well as for gathering foreign intelligence. This was related to the organizational location of the COMINT function within the navy's communication command, not the Office of Naval Intelligence (ONI). The organizational separation made the integration of COMINT with other intelligence sources even more problematic. Another significant difference was that, following a considerable period of suspicion and sparring, the navy and army COMINT organizations established a wary but reasonably effective system of cooperation. Until the late 1930s, the IJN's crypto systems seem to have been generally more secure than those of the USN, but navy cryptanalysts nevertheless managed the formidable feat of breaking the two-part superenciphered code that their Japanese counterparts introduced in 1930.[105]

- **Operational planning and logistics.** In 1907-08 President Theodore Roosevelt dispatched the "Great White Fleet" on a 46,000 mile around-the-world cruise of 14 months. The logistics problems were formidable but the navy surmounted them, learning a great deal in the process which formed a basis for planning of Transpacific operations. In the 1930s, the USN's fleet problems often were conducted thousands of miles from their bases, involving considerable operational and logistics planning. In late 1939, Hawaii for the first time became a permanent base for some ships, and this was followed a few months later by President Franklin D. Roosevelt's order to keep the entire battlefleet at Hawaii as a deterrent. This was the first time that a major portion of the fleet had been based outside the continental U.S. and taught many important les-

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[105] Frederick D. Parker, *Pearl Harbor Revisited: United States Navy Communications Intelligence, 1924-1941,* United States Cryptologic History, Series IV, World War II. Vol. 5, Fort George G. Meade, Maryland: Center for Cryptologic History, National Security Agency, 1993.

sons about forward logistical support. Thus, notwithstanding relative neglect of the logistical side of operational planning at the War College, the navy developed a de facto body of doctrine and expertise in planning of major operations and their supporting logistics.[106]

U.S. Marine Corps

The U.S. Marine Corps was independent enough of the USN to pursue its own transformation agenda without detailed input or oversight from its nominal parent, but not so independent as to make it irrelevant to the navy's plans. Marine development of amphibious assault was clearly important if the navy was to succeed in gaining bases among the Japanese-held islands of the Central Pacific. There were other important elements that received much less attention because of lack of an institutional champion like the USMC.

After accepting the challenge of amphibious assault, the Marine Corps conducted a series of small-scale exercises in the 1920s to explore the concepts. (With no more than 20,000 troops, of course, the Corps could do nothing but small scale efforts in any event.) These served mainly to demonstrate that nothing was simple in amphibious operations and to show a number of ways not to do it. But they did provide material for thought, and the USMC's newly-created Marine Corps Schools offered a good place to do the thinking. By the time commitments elsewhere combined with Depression force and spending reductions to curtail further experimentation in 1927, some progress had been made and enough experience had been gathered to keep Marines thinking over the years to come.[107]

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[106] Duncan S. Ballantine, *U.S. Naval Logistics in the Second World War*, Princeton: Princeton University Press, 1947, pp. 25-37; and Gerald John Kennedy, "The United States Naval War College, 1919-1941: An Institutional Response to Naval Preparedness," Ph.D. diss., University of Minnesota, Minneapolis, 1975, *passim.*

[107] Allan R. Millett, *Semper Fideles*, pp. 322-31.

Japanese Army

The IJA's concern was largely for conflict with the Soviet Union, but it acknowledged the possibility of hostilities with America and the resultant need to conquer the Philippines. The army entertained a greater diversity of views and some broader visions than the navy. Visionaries within the service who looked to an eventual confrontation with the West laid serious plans to transform not simply the army but the nation so as to prepare to meet the industrialized nations on equal terms. By the late 1930s, however, this grand transformative vision and the men who held it had lost out in the struggle to direct army and national policy.[108] Thereafter the IJA stuck relatively strictly to upgrading its forces within the structure of its existing doctrine of fast-moving, aggressive encircling attacks by infantry limited support by other arms. As with the navy, the Japanese Army's operational and strategic doctrine amounted to little more than *attaque à l'outrance* and trust in heaven.

The army developed its tactical doctrine and matériel in a wide variety of areas, notably:

- **Amphibious operations.** The IJA's amphibious concepts did not extend to assaults on defended shores but envisioned landings, often in darkness, at lightly defended locations followed by rapid overland marches to engage the enemy. A variety of matériel innovations were made, including ramped landing craft and a well-deck ship.[109]
- **Armor.** In contrast to the U.S. Army, the IJA was relatively progressive in development of armored forces. Japanese engineers designed sound tanks which were produced in considerable

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[108] Michael A. Barnhart, *Japan Prepares for Total War, passim.*

[109] Edward J. Drea, *In the Service of the Emperor,* pp. 14-25; David C. Evans and Mark R. Peattie, *Kaigun,* pp. 441-446; and Allan R. Millett, "Assault From the Sea: The Development of Amphibious Warfare Between the Wars – the American, British, and Japanese Experiences," in *Military Innovation in the Interwar Period,* edited by Williamson Murray and Allan R. Millett, Cambridge: Cambridge University Press, 1996, pp. 64-70.

quantity. As in most armies at the time (including that of the U.S.), IJA doctrine envisioned the tank as supporting infantry, not as a major arm in its own right. The emphasis was on light and light medium tanks, seen as best suited to the conditions in Northeast Asia.[110]

- **Aviation.** The army's air force was developed as an adjunct to ground operations rather than as an independent strategic force on the British model. Following the conquest of Manchuria in 1931-32, the army air doctrine shifted from reconnaissance and attack to more emphasis on guaranteeing air superiority over the battle area, with preemptive attacks to suppress enemy air forces at the outset.[111] Together with the IJN, the IJA fostered the development of a domestic aircraft industry in the absence of significant commercial markets and by the late 1930s Japan was producing military aircraft that were as good as if not better than those made in Europe and America. On the whole, however, the IJA tended to lag the IJN slightly in aircraft technology. Its first semi-streamlined monoplane fighter, the Nakajima Ki-27, did not enter service until more than a year after the broadly comparable naval A5M. Similarly, its first twin-engined streamlined monoplane bomber, the Mitsubishi Ki-21, lagged behind the navy's G3M.[112]

- **Infantry.** Infantry had been the dominant arm in Japanese warfare since Nagashino in 1575. After World War I the IJA became well aware that some armies were putting greater emphasis on other arms, notably artillery and armor, but continued to put infantry very much in the lead in its own doctrine. In part, of course, there were economic motivations for this, but the army naturally made a virtue of the necessity in any event. To maximize infantry combat power the army placed

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[110] Edward J. Drea, "The Imperial Japanese Army," pp. 90-1; Richard M. Ogorkiewicz, *Armor: A History of Mechanized Forces,* New York: Frederick A. Praeger, Publishers, 1960, pp. 250-56.

[111] Eiichiro Sekigawa, *Pictorial History of Japanese Military Aviation,* p. 38.

[112] René J. Francillon, *Japanese Aircraft of the Pacific War, passim.*

> tremendous stress in aggressive tactical doctrine, rigorous training, and development of *seishin* – [martial] spirit. The best officers went to the infantry for their troop assignments and the Japanese foot soldier was provided with simple but lightweight and high-quality equipment. Many observers question whether any army produced light infantry to match that of the IJA in tactical proficiency or determination.[113]

This is unquestionably a relatively thin diet of transformation. After 1936 army leaders had more ambitious ideas for new weapons and remodeled forces, but these quickly became casualties of the China conflict.

U.S. Army

The U.S. Army seems to have shown less top-level transformational leadership than any of the other services in this survey. Nevertheless, some significant transformation effort did take place. Like the Navy, the Army had a very fragmented military leadership structure with many independent and semi-independent organizations reporting only to the Secretary of War – a structure fostered in large part by a Congress as a measure of control and a barrier to militarism. This fragmentation allowed different arms and branches to pursue divergent or competitive agendas, at least to an extent. The most notable example is the Army Air Corps, which I treat separately below.

As a result of its relatively small budgets and decision to emphasize potential to raise the largest possible mass army over a period of 6 to 12 months of mobilization rather than to build a small but modern force, the service was severely constrained in resources for modernization of any kind. There was some interest in development of armored forces but it was very hesitant and sporadic until the shock of German successes in 1939-40 stimulated more concerted action. It would not be accurate to label this as a major focus of army trans-

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[113] Edward J. Drea, *In the Service of the Emperor*, pp. 60-61, 63-65, 68-69.

formation in the U.S.[114] What funding could be gained for matériel transformation went almost exclusively to the Air Corps.

The main areas in which important transformative efforts did take place were:

- **Motorization.** In a way it seems inevitable that the U.S., with its huge, pioneering auto industry, would motorize its army. In fact, the army had gone to war in 1918 with a great many motor vehicles, mostly of various commercial types. This was not terribly satisfactory, however, and it took considerable time and effort to develop policies that would allow the army to meld the strength of the automotive industry with military requirements for performance and logistical supportability. This was one area outside of military construction where the army got some benefit from Depression relief funds.[115] To some extent, motorization was stimulated (or at least justified) by the decline in the horse population in the U.S.[116]

- **Engineer equipment.** The Corps of Engineers continued to attract the cream of West Point graduates. Because its officers alternated between civil projects and military assignments, they were well aware of (and in many cases led) advancements in construction machinery and eager to apply them to field engineering tasks. The Corps also pursued advances in aerial mapping. In matériel for field bridging and airfield runway surfac-

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[114] Raymond E. Bell, Jr., "Evolving Army Armor Structure In the Late 1920s," *Armor*, Vol. 110, No. 4 (Jul-Aug 2001), pp. 29-37; David E. Johnson, *Fast Tanks and Heavy Bombers, passim*; and John B. Wilson, "Organizing the First Armored Divisions," *Armor*, Vol. 108, No. 4 (Jul-Aug 1999), pp. 41-3.

[115] Daniel R. Beaver, "Politics and Policy: The War Department Motorization and Standardization Program for Wheeled Transport Vehicles, 1920-1940," *Military Affairs*, Vol. 47, No. 3 (Oct 1983), pp. 101-8.

[116] Boyd L. Dastrup, *King of Battle: A Branch History of the U.S. Army's Field Artillery*, Fort Monroe, Virginia: Training & Doctrine Command, U.S. Army, 1992, p. 192.

ing, however, there was slow progress until after reports began coming in of the war in Europe.[117]

- **Communications.** In the First World War, the mainstay of army communications in France had been telephone and telegraph over wire circuits. The Signal Corps had not been well prepared for the age of electrical communications and found itself very dependent on allied help. During offensives it was necessary to lay up to 2,500 miles of wire per week. By war's end the Signal Corps had (including leased lines) nearly 100,000 miles of wire in France. Wire was supplemented by homing pigeons and radio, both of which were cranky. In the 1920s and early 1930s signal officers bickered with other branches, built up their capacity to lay wire, developed field telephone equipment, bred pigeons, and – in concert with America's flourishing radio industry – worked to develop radios that could operate reliably and effectively in the field. All on very meager budgets.[118]

- **Coastal defense.** The phrase tends to bring to mind images of moldering fortifications and the hulks of big guns that never fired a shot in anger. Between the world wars, however, coastal defense remained a key and widely-supported army mission. Fortifications and seacoast artillery continued to play a part in defense of port cities and naval bases as well as the termini of the Panama Canal, but it was recognized that they had to be supported with defenses against air attack and against forces landed at unfortified places. Doctrine for defense against landing was transformed with the wide acceptance of Brigadier General William G. Haan's 1920 proposal of a flexible mobile

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[117] Blanche D. Coll, Jean E. Keith and Herbert H. Rosenthal, *The Corps of Engineers: Troops and Equipment,* United States Army in World War II: The Technical Services, Washington: Office of the Chief of Military History, U.S. Army, 1958, pp. 27-91.

[118] Dulany Terrett, *The Signal Corps: The Emergency (To December 1941),* United States Army in World War II: The Technical Services, Washington: Office of the Chief of Military History, Department of the Army, 1956, pp. 16-34, 48-69, 110-21, and 221-3.

defense-in-depth doctrine which still seems modern in overall concept.[119] In Hawaii in particular, where the threat of Japanese attempts to seize Oahu could not be altogether dismissed, very effective invasion defenses were developed along the lines laid out by Haan. But in the Philippines, lack of forces to defend the many stretches of practicable landing areas on Luzon made effective defense infeasible.[120]

- **Field artillery.** As is well known, American field artillery in World War II was greatly respected by friend and foe alike. How it achieved this eminence makes a rather strange story, for in many respects the field artillery branch was quite backward for most of the interwar years, clinging to the 75 mm gun and horse traction and quickly abandoning experiments with self-propelled guns. Innovative field-grade officers at the Field Artillery School developed the doctrine and matériel for a radical change in fire direction, aimed at permitting entire battalions or divisional artillery regiments to mass fires swiftly, but their ideas met with strong resistance. New 105 mm and 155 mm howitzers were developed, along with new shells and more practical and flexible fuzes, but they were not put into wide service and doctrine regarding divisional artillery remained in flux. Naturally, little was done to develop antitank doctrine or systems, and nothing to prepare artillery to play a role in an armor-heavy combined-arms force. Not until after

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[119] "A Positive System of Coast Defense (Army)" in *Joint Army and Navy Action in Coast Defense,* Department of War and Department of the Navy, Washington: Government Printing Office, 1920; and Brian McAlister Linn, "Peacetime Transformation in the U.S. Army, 1865-1965," in *Transforming Defense,* edited by Conrad C. Crane, Carlisle, Pennsylvania: Strategic Studies Institute, U.S. Army War College, 2001, p. 14.

[120] Brian McAlister Linn, *Guardians of Empire: The U.S. Army and the Pacific, 1902-1940,* Chapel Hill: University of North Carolina Press, 1997, *passim,* but particularly 219-246.

war had broken out in Europe did the army truly address artillery transformation.[121]

- **Radar.** Following exposure to very early and primitive radar research at NRL in 1930, the army's Signal Corps Laboratory took up radar development of its own. Interchange with NRL was spotty, due to interservice rivalries and suspicions. Development was also bedeviled by army bureaucratic and fiscal obstacles. Nevertheless, after learning of the idea of pulsed operation from NRL, the Signal Corps engineers developed two VHF sets one of which, the air early warning SCR-270, was highly successful and served until the end of World War II. Once the developers had prototypes to demonstrate they gained high-level support. Industry initially showed little interest, prompting the in-house development (which was contrary to stated army policy) but RCA and others later made significant contributions.[122]

- **Communications intelligence.** The U.S. Army also built up a COMINT capability, particularly in the 1930s. It had little opportunity to practice intercept and collection against IJA low power field transmitters but developed a particularly strong staff of civilian (and hence long-serving) cryptanalysts. The navy, absorbed in attacking IJN communications, willingly passed diplomatic intercepts to the army to work on. The Japanese, well aware of earlier U.S. successes in reading their diplomatic codes, introduced machine cipher systems in the

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[121] Boyd L. Dastrup, *King of Battle,* pp. 179-201; Boyd Dastrup, "Travails of Peace and War: Field Artillery in the 1930s and Early 1940s," in *The U.S. Army and World War II: Selected Papers From The Army's Commemorative Conferences,* edited by Judith L. Bellafair, Washington: Center of Military History, U. S. Army, 1998; and Janice McKenney, "More Bang for the Buck in the Interwar Army: The 105-mm. Howitzer," *Military Affairs* Vol. 42, No. 2 (Apr 1978), pp. 80-6.

[122] Henry E. Guerlac, *RADAR in World War II,* 2 vols., Los Angeles/New York: Tomash Publishers/American Institute of Physics, 1987, Vol. 1, pp. 93-117; S[ean] S. Swords, *Technical History of the Beginnings of RADAR,* pp. 112-18; and Dulany Terrett, *The Signal Corps: The Emergency,* pp. 39-48 and 121-29.

1930s. The second of these, the Type B, was in principle a very secure system.[123] Aided by some errors in its design and employment, however, the army's cryptologists managed, by a great and extraordinarily skillful effort, to solve the system, build working replicas, and recover daily keys with good to excellent timeliness. This MAGIC (as it was codenamed) produced a steady flow of high-level diplomatic message decrypts that were circulated to top U.S. officials.[124]

- **Operational planning and logistics.** Operations over the vast spaces of America had always posed extraordinary challenges of movement and logistics for the U.S. Army and had no doubt fostered particular awareness of these aspects of war. It was the experiences of World War I, however, that shaped army interest and attitudes in the 1920s and 1930s. Starting with 200 thousand troops on active duty in April 1917, an army of 4 million was raised and trained over the next 19 months, with half of it reaching France. No nation had ever attempted the feat of moving a huge army across and ocean and supporting it in combat. The army was proud of its accomplishment, but also very aware of the shortfalls and limitations that it had encountered.[125] As it conceived its mission to be readiness for another such buildup and dispatch of troops to another great conflict, it naturally made large-scale operational and logistical planning a major subject of study at its Command and General Staff College, which most mid-level officers attended between the wars. Though it may seem somewhat odd to include this among transformative efforts, in fact it was a significant departure not only from the army's own past but from the pattern of

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[123] The Type B is often called by its U.S. code name, PURPLE.

[124] Edward J. Drea, *MacArthur's ULTRA: Codebreaking and the War Against Japan, 1942-1945*, Lawrence, Kansas: University Press of Kansas, 1992, pp. 8-12; and Stephen J. Kelley, *Big Machines: Cipher Machines in World War II*, Walnut Creek, California: Aegean Park Press, 2001, pp. 74-107, 172-186, and 210-216.

[125] Leonard P. Ayres, *The War With Germany: A Statistical Summary*, Second Edition, Washington: Department of War, 1919, pp. 37-100.

other armies (including especially the IJA) and one which was to have a very great effect on the war to come.[126]

U.S. Army Air Corps

While the Air Corps was organizationally tied to the Army in this period, it pursued a transformation agenda that was largely separate and significantly at cross purposes to that of its parent service.[127]

At the most fundamental level, of course, it wanted to transform itself into an independent service. Air Corps leaders might waver in the extent to which they sought complete organizational independence but strategic and operational independence was always pursued and often loudly demanded. And hopes of getting a larger budget share as an independent service drove them often to insist on complete separation.[128] Inevitably, this made for tense relationships with the rest of the army and its General Staff.

In the view of the army's airmen, independent "strategic" air power was destined to be the great arbiter of wars, ready to assume the role

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[126] Edward J. Drea, *In the Service of the Emperor*, pp. 72-74.

[127] For a current critical survey of interwar thinking on air doctrine in the U.S., with references to other literature, see Tami Davis Biddle, *Rhetoric and Reality in Air Warfare: The Evolution of British and American Ideas About Strategic Bombing, 1914-1945*, Princeton: Princeton University Press, 2002, pp. 128-75. Other valuable surveys from views more closely in sympathy with the airmen can be found in Robert Frank Futrell, *Ideas, Concepts, Doctrine: A History of Basic Thinking in the United States Air Force, Volume I, 1907-1960*, Maxwell Air Force Base, Alabama: Air University, 1971, republished 1989, pp. 61-114; and Thomas H. Greer, *The Development of Air Doctrine in the Army Air Arm, 1917-1941*, Maxwell Air Force Base, Alabama: USAF Historical Division, Research Studies Institute, Air University, 1955, pp. 14-106. For more specifics about ground attack see Lee Kennett, "Developments to 1939," in *Case Studies in the Development of Close Air Support*, edited by Benjamin Franklin Cooling, Washington: Office of Air Force History, 1990.

[128] James P. Tate, *The Army and its Air Corps: Army Policy Toward Aviation, 1919–1941*, Maxwell Air Force Base, Alabama: Air University Press, 1998, p. 187.

almost immediately. Other forms of military action might have a place, but only a very subsidiary one. Air power had to be unfettered and controlled solely by qualified airmen to fulfill its potential. Anyone who did not subscribe to this doctrine with enthusiasm had little future in the Air Corps.

Finding the technology to match the doctrine posed a challenge. In 1933 the Air Corps' best "heavy" bomber in frontline service was the Keystone B-6A, a 13,000 lb fabric-covered biplane whose two 575 horsepower engines allowed it carry 2,500 lb of bombs a total of 315 nmi at a speed of 90 kt. In practical terms it could reach targets not much more than 100 nmi from its base. Flying at an altitude of 5,000 ft it could bomb with reasonable accuracy even with primitive bomb sights, but even at maximum bombing altitude of 10,000 ft was a good target for the 3-inch antiaircraft guns of the day. And its top speed of 100 kt and lack of protection made it possible for lightly-armed biplane fighters to intercept and destroy it.[129] This was an improvement over the bombers of World War I, 15 years earlier, but no more than a marginal one. Only the most dedicated enthusiasts could see in this a potential for strategic decision.

The Air Corps had faith in the potential of airplane performance but no clear strategy for realizing it. Nevertheless, Air Corps funding of a variety of technologies and Air Corps markets for powerful engines played an important role in facilitating the aeronautical revolution of the 1930s. By 1933 streamlined aluminum-skinned monoplane airliners were in service and the next year the Air Corps began taking deliveries of the first models of its new Martin B-10. In its full production version, the B-10B delivered in 1935, it weighed 1,250 lb more than the Keystone and with 50% more power could fly 85% faster. It could carry 2,260 lb of bombs more than 500 nmi at 165 kt – a range that could be doubled by overloading with fuel. It carried three machine guns for defense but scarcely needed

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[129] Ray Wagner, *American Combat Planes*, p. 37.

them, for its speed and ceiling put it out of reach of any existing fighter.[130]

Dramatic as this improvement was, it still fell short of Air Corps goals. The experimental four-engined XB-17, flown in mid 1935, seemed to offer performance that would at last begin to fill air power's need. The immense expense of the B-17 – twice that of the Martin and four times as much as the Keystone – raised doubts, as did its seemingly "offensive" character, but eventually the Air Force won approval to order the first 38 production B-17s. These B-17Bs, which started to reach service in 1938, weighed nearly 38,000 lb, developed 4,000 horsepower from their four supercharged engines, and could reach 250 kt at 25,000 ft. With 4,000 lb of bombs they could fly 2,100 nmi at 200 kt.[131] Bomber performance had been dramatically transformed since the B-6A. To men who had five years before had been flying in the open cockpits of biplanes, it seemed as if a new world had opened.

Fighter, observation, and attack aircraft also could benefit from the aeronautical revolution but their progress was more halting. The obstacles were not primarily technical. In the Air Corps' vision of transformation, all these types were distinctly secondary to the heavy bomber. The airmen did not expect every bomber to reach its target, but believed that most would if the attack was carefully planned and boldly executed. They envisioned the modern industrial nation as a "web" of interdependent links. If the key links were identified and destroyed at the outset of war by bombing raids, the whole web would collapse and with it the enemy's capacity to resist – to say nothing of bombing's effects on his will to continue. Thus the bomber's powers of strategic decision made the operations of the conventional land and sea forces that other airplanes were intended to support all but irrelevant.

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[130] Ray Wagner, *American Combat Planes*, pp. 195-98.

[131] Ray Wagner, *American Combat Planes*, pp. 200-206.

Proponents of strategic bombing were further confirmed in their views by the seeming immunity from defenses offered by the B-17's performance. It could bomb from heights beyond the reach of the army's antiaircraft artillery. And its combination of speed and altitude made it all but impossible to intercept with the Air Corps' best fighters. In any event, with bomber performance improving at so breathtaking a pace, who could doubt that any remaining obstacles would soon be overcome?

But in part this was a self-fulfilling prophecy, for the service had put little emphasis on fighter performance. It is certainly telling that in the 1930s Boeing, one of the very strongest and technically advanced of military-oriented aircraft firms, turned away from the fighters which had long been a major area of strength for the company to concentrate on large bombers.[132] The fighter was a less attractive market, left to firms like Curtiss (a big firm with fighter experience which had been late in making the transition to streamlined monoplanes and lost markets as a result) and Seversky (an ill-capitalized newcomer with management problems and no prior fighter experience). When the Air Corps sought advanced fighter concepts it turned to Bell and Lockheed, small firms with innovative ideas but no fighter experience and limited production capacity (particularly in Bell's case). In Japan and other nations the strongest airplane builders vied for fighter business, but not in America.

In looking for a bombsight to match the B-17's potential the Air Corps was chagrinned to find that the best was in the hands of the rival USN. The navy's Bureau of Ordnance (BUORD) had sponsored engineer Carl Norden to develop an intricate and complex electro-mechanical computing sight that partly automated the complex calculations necessary to make all the corrections required to compensate for the errors involved in dropping bombs from great heights. This seemingly odd arrangement was a natural outgrowth of BUORD's development of advanced computing systems for shipboard fire control. By the mid 1930s the navy had lost much of its

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[132] Peter M. Bowers, *Boeing Aircraft Since 1916*, London: Putnam, 1966, p. 173.

interest in level bombing, convinced that it could never offer much of a capability for hitting ships at sea. Norden, an irascible eccentric, would deal with no one but BUORD and so the Air Corps, rather uncomfortably, got its Nordens by way of the navy.[133]

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[133] Stephen L. McFarland, *America's Pursuit of Precision Bombing, 1910-1945*, Washington: Smithsonian Institution Press, 1995, pp. 68-104.

Lessons from experience

Naturally, transformation efforts were adjusted, refined, and redefined over time. It is particularly relevant, however, to examine how they were modified in response to the lessons drawn from experience, particularly at the end of the interwar period.

Sources of experience

There are six sources of experience that merit particular attention: technical tests and experiments, war games, operational tests and experiments, combat experience, the combat experience of others, and operations analyses. Each influenced transformation, positively or negatively, in each nation and service.

Technical tests and experiments

In a period of rapid introduction of new systems and improvement of old, it becomes vital to gather information about their technical performance. Of particular importance are those aspects of performance that may be difficult or impossible to observe directly in ordinary peacetime training exercises, such as weapon accuracy and damage effects. Generally this requires thoughtfully-constructed and carefully-analyzed tests of actual system hardware or suitable analogs. Poorly constructed or conducted tests can yield significantly misleading information.

In general, there were many serious deficiencies in technical experimentation and testing between the world wars. Many systems were very inadequately tested, and some not at all.

War games

War gaming played a prominent role in the curricula of the Japanese and American naval war colleges and the war college gaming facilities were also used for development of concepts and plans. The same holds true for the U.S. Army War College. I have seen no evidence of comparable gaming efforts at the IJA's war college or at the U.S. Army Air Corps Tactical School.

In many ways the U.S. Naval War College at Newport, Rhode Island, was the *fons et origo* of serious war gaming. It certainly exercised a strong influence on war gaming at Japan's naval war college. Both strategic and tactical games were played intensively at Newport between the wars and there is little doubt that they yielded many highly valuable insights. Nevertheless, students of the games have identified a number of limitations:[134]

- Models regarding the effectiveness of sensors and weapons were sometimes weak either through lack of data or inadequate appreciation of the physical or psychophysical factors. Those who ran the games did the best they could with the data available, but it often was insufficient.
- The level of aggregation was sometimes so high as to mask critical effects. Of course this was difficult to avoid owning to the very limited technology available for calculation.
- The three-minute time step used for tactical games was too coarse for some purposes and it could take far longer than three minutes to evaluate a move, thus giving the participants a leisure they would not enjoy in combat. Again, the limits of available technology made these problems largely unavoidable.

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[134] Mark Allen Campbell, "The Influence of Air Power Upon the Evolution of Battle Doctrine in the U.S. Navy, pp. 100-107; T. J. McKearney, "The Solomons Naval Campaign, pp. 107-129; and Peter P. Perla, *The Art of Wargaming: A Guide for Professionals and Hobbyists,* Annapolis: Naval Institute Press, 1990, pp. 70-76.

- Preconceptions about naval warfare and its problems conditioned the situations gamed and the setups used, resulting in stereotypical games that failed to address some important issues. This may well have been at least in part a reflection of resource constraints – there were limits on how many games (and particularly on how many entirely new scenarios) could be played, and the games had to serve didactic as well as experimental purposes.

There do not seem to be any comparably insightful studies of wargaming at other institutions but it seems likely that similar problems were encountered elsewhere.

Operational tests and experiments[135]

The USN conducted a series of "fleet problems" between the wars which combined training with deliberate exploration of tactical and operational concepts. These are celebrated, and surely with justice, for they helped greatly in the development of aircraft carriers and the doctrine for employing them.[136] Nevertheless, these experiments suffered from important limitations too.[137] A central problem was that of assessment of weapon hits and damage. This had to be done in real time. Umpires were eventually provided with guidelines, but even so a large measure of judgment was necessarily left to them. Naturally, these judgments reflected their experience and organizational interests to some degree. Moreover, the rules and guidelines suffered from the same uncertainties as those at Newport. The result again was some bias toward self-fulfilling prophecies.

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[135] For a broad analysis of interwar experimentation see Brian McCue, *Wotan's Workshop: Military Experiments Before the Second World War,* Center for Naval Analyses, Oct 2002.

[136] Mark Allen Campbell, "The Influence of Air Power Upon the Evolution of Battle Doctrine in the U.S. Navy, pp. 146-179.

[137] Mark Allen Campbell, "The Influence of Air Power Upon the Evolution of Battle Doctrine in the U.S. Navy, pp. 119-45; and T. J. McKearney, "The Solomons Naval Campaign," pp. 129-36.

A more fundamental problem was the lack of effective analysis. "Lessons learned" were promulgated by the fleet commander, but these were not founded on careful exercise reconstruction and analysis. This again made it less likely that the exercises would reveal unexpected results.

Whatever their defects, the USN fleet problems appear to have been the most ambitious efforts of their kind in either nation. The U.S. Army conducted exercises but for most of the interwar period these were almost exclusively on very small scales and focused on training rather than experiment. Only in Hawaii were there enough troops in one place to exercise even at the brigade level, and here tests were made of invasion defenses. Not until the autumn of 1941, two years after war had begun in Europe, did the army initiate its first large-scale maneuvers in more than 20 years. These great exercises in Louisiana and the Carolinas were really intended for training but did have effects on doctrine, particularly with respect to armor and anti-armor forces. These suffered from the self-fulfilling prophecy problem in some respects, however, particularly with regard to the concept of tank-destroyer forces.[138]

As in other matters, the Air Corps was relatively better provided for than the ground forces in regard to funds for exercises. Some of their efforts were devoted to technical or fairly narrow tactical tests, but so far as I know they did no large-scale experiments.

The Marine Corps did some exercises relating to their amphibious assault concept, but nothing that tested major aspects of it on a broad scale.[139]

The IJN conducted annual fleet exercises in home waters but these appear, from surviving records and accounts, to have been largely for training purposes, although accidental casualties during maneu-

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[138] Christopher R. Gabel, *The U.S. Army GHQ Maneuvers of 1941*, Washington: Government Printing Office, 1991, pp. 185-94; and David E. Johnson, *Fast Tanks and Heavy Bombers*, pp. 148-52.

[139] Brian McCue, *Wotan's Workshop*, pp. 17-18.

vers did reveal some shortcomings in ship design and construction that were at least partly corrected as a result.[140] The IJA annual maneuvers seem also to have been largely training exercises. I have seen little to suggest that either service engaged in serious analysis of exercises and their results, although I cannot rule this out.

Combat experience

The U.S. forces had only minor combat experience between the world wars and did not regard what they had as relevant to preparing their forces for major war, although it did provide a limited amount of experience under fire.

Japanese forces of course engaged in large-scale combat with China from 1937 onward. The China war provided experience not only for the IJA but for the air elements of the IJN as well.[141]

The IJA was skeptical about the relevance of experience in China to a major war due to the low state of training and equipment of most Chinese forces. Two major clashes with Soviet forces, however, gave a clear taste of combat with a more formidable foe. The sharp defeat in corps-level combat at Nomonhan (Khalkhin-Gol) in the summer of 1938 led to a thorough review – but oddly little attention seems to have been paid to its findings. It appears that they were simply too at odds with the basic doctrine of the IJA, especially with respect to the overriding value of *seishin* ("spirit"), to permit assimilation.[142] In any event, the army lacked the resources to pursue most of them, particularly with the ongoing war in China.

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[140] David C. Evans and Mark R. Peattie, "Ill Winds Blow," U. S. Naval Institute, *Proceedings*, Vol. 123, No. 10 (Oct 1997), pp. 70-3; and *idem, Kaigun*, pp. 210-211 and 240-245.

[141] Mark R. Peattie, *Sunburst*, pp. 102-128.

[142] Edward J. Drea, *In the Service of the Emperor*, pp. 1-13.

Combat experience of others

There were several major episodes of combat in Europe before the outbreak of war between Japan and the U.S., and these served as sources of second-hand experience. The Spanish Civil War, which provided much important experience to Germany, seems to have made relatively little impression either on Japanese or American forces. It held little interest for the USN and does not seem to have been studied at all intensively by the IJN. The U.S. Army made some efforts to collect information about the conflict, but read it primarily as substantiating the service's preexisting doctrine and expectations.[143] The Air Corps dismissed it as irrelevant because no one had followed what it felt sure was the only correct doctrine for an air force.[144] The IJA seems also to have seen it largely as confirming its presuppositions.[145]

The outbreak of fighting between Germany and the Allies in Europe made a greater impression, at least in some ways. There is no doubt that the fall of France in the summer of 1940 in particular brought a much sharper perception of threat among Americans generally. It also heightened army interest in combined arms warfare with a strong armor component – a story which is not very relevant to the theme of U.S.-Japanese competition and conflict, given that armor was not envisioned as having a role in it before the war.[146] The role played by the *Luftwaffe* in *Blitzkrieg* renewed Air Corps interest in ground attack, although it was anything but wholehearted.[147] Note was taken of the various failings of British and

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[143] William O. Odom, *After the Trenches*, pp. 139, 150-65 *passim*, and 216-18.

[144] Tami Davis Biddle, *Rhetoric and Reality in Air Warfare*, pp. 171-73; and Lee Kennett, "Developments to 1939," pp. 48 and 59-60.

[145] Edward J. Drea, "The Imperial Japanese Army," p. 91.

[146] Kevin C. Holzimmer, "In Close Country: World War II American Armor Tactics in the Jungles of the Southwest Pacific," *Armor*, Vol. 106, No. 4 (Jul-Aug 1997), p. 22.

[147] Lee Kennett, "Developments to 1939," pp. 52-56.

German bombing efforts, but again these tended to be laid to faulty doctrine and equipment.

The war in Europe also brought naval action. Indeed, the USN became actively involved in "Neutrality Patrol" and eventually in escorting convoys to Iceland, during which it gained direct experience in antisubmarine warfare and lost a ship to a U-boat torpedo.[148] The lessons drawn from the many ships of Britain's Royal Navy that were lost to or damaged by German air attacks also influenced the USN.

There is little to suggest that either the IJN or IJA took much from the European experience, despite their close relations with the German military.

In one respect, however, both nations gained significantly from their informal alliances, the U.S. with Britain and Japan with Germany. Japan sent a delegation to Germany in 1941 which brought back much valuable information about technical developments and stimulated various aspects of Japanese research. The U.S., which first sold and then gave combat aircraft and weapons to the Allies, learned much about the technical lessons of European warfare as a result. And in 1940 a British technical mission to the U.S. brought immensely valuable information regarding radar and other developments.[149]

Operations analysis

The definition I use of operations analysis (OA) is that it is *the application of the methods and subject knowledge of the sciences to the analysis of*

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[148] Samuel Eliot Morison, *The Battle of the Atlantic, September 1939 - May 1943,* History of United States Naval Operations in World War II, Vol. 1, Boston: Little, Brown & Co., 1947, pp. 57-113.

[149] E. G. Bowen, "The Tizard Mission to the USA and Canada," in *Radar Development to 1945.*

operations.[150] Military staffs had been practicing OA in this sense in very limited ways time out of mind, and scattered examples are to be found in the U.S. at least back to the early days of the 20th century. There was nothing like any broad and systematic application of OA such as developed in Britain in the mid to late 1930s, however.[151] In Japan, the application of OA was if anything even less. This was costly, as the British experience demonstrates – the number of problems amenable to OA was large in the interwar years and grew steadily with time, and in the cases where it could be applied OA was much the fastest and least expensive way to gain feedback.[152] There is no question that OA could have contributed a great deal to the effectiveness of war games and experiments in influencing interwar transformation.[153]

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[150] The definition is my own, deriving from more than four decades of involvement in an observation of operations analysis activities. I explicitly take mathematics to be a science, growing from empirical rather than transcendental roots.

[151] Air Ministry, *The Origins and Development of Operational Research in the Royal Air Force,* Air Publication 3368, London: Her Majesty's Stationery Office, 1963, pp. 1-9.

[152] A sense of the kinds of problems in which OA might have been fruitful in this period can be gained from Philip M. Morse and George E. Kimball, *Methods of Operations Research,* Cambridge: MIT Press, 1951.

[153] Brian McCue, *Wotan's Workshop.*

Transformation's end-games

Having gotten feedback from these sources those pursuing various transformative initiatives pushed them to their conclusion, or at least as far as was possible in the time remaining until 7 December 1941. While no one knew the final deadline until late in 1941 (and then only a few in Japan), there was a very widespread and growing appreciation of the likelihood and imminence of conflict throughout the latter half of 1940 and through 1941. This was thus a period dominated by a strong sense of urgency.[154]

Japanese Navy

The IJN made some important improvements and adjustments in its air posture but largely hewed to incremental changes in other areas. Through exercises beginning only in 1938 it rather belatedly discovered that its plans for employing submarine forces to warn of American fleet movements and exact heavy early attrition were seriously flawed. This threw the navy's submarine doctrine into a turmoil from which it never effectively recovered, severely reducing its effectiveness in the war to come.[155] This is a good example of the sort of problem that operations analysis could have been expected to warn of early, and help to resolve.

Surface forces

Another major element of the navy's "outranging" ideal was night attack by destroyers and cruisers, supported by fast battleships. Here

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[154] In many cases the material for this section is drawn from the same sources as that in the section on "Objects of transformation", *supra*. In these cases I do not repeat the citations.

[155] David C. Evans and Mark R. Peattie, *Kaigun*, pp. 428-34.

the IJN made no major adjustments and the results of the night battles in the Solomons in 1942-1943 (albeit under quite different circumstances) suggest that doctrine in this area was largely sound and supported with matériel well suited to its execution.[156] Torpedo hit probabilities do no appear to have approached the expectation of 10%, however.[157] It seems very likely that timely development of radar and effective integration of it into night doctrine would have paid dividends.

It was also expected that destroyers and cruisers would deliver a massive torpedo attack at long ranges in the opening stages of a daylight engagement between battlefleets that would achieve 10% or greater hit rates. While the navy's large oxygen torpedo had the requisite range, it seems clear that nothing approaching 10% hit probabilities were in prospect. Long range tests under free-play conditions were inhibited by concerns about security, as well, no doubt, as by cost. Again, this is an area where timely operations analysis of the likely errors could have given early warning of problems and perhaps have helped find solutions.

It was recognized by both sides that earlier Japanese battleships were not as well protected as their American counterparts, having sacrificed protection for speed and gunpower. Upgrades in the 1930s could and did strengthen the protection, but it was not possible to bring it up to parity. In the *Yamato* class super-battleships these defects were to be remedied by making the ship large enough (and hence costly enough) to meet all needs. War experience showed that protection against torpedoes was not as good as planned, although some of this may be attributed to the torpedoes having more powerful warheads (due to the Allied development of improved explosives) than had been anticipated in the design of the

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[156] T. J. McKearney, "The Solomons Naval Campaign," pp. 149-59.

[157] Ibid., pp. 141 and 195.

ships.[158] On the whole, however, these ships had formidable capabilities in their intended role.

But of course they never fought in that role. Indeed, they scarcely fought at all, except for their final death-rides. The contributions made by these ships, in which so much had been invested and from which so much was expected, to Japan's defense were negligible. Of course this was due to the rise of naval aviation forces – it was symbolic that both the *Yamato* and its sister battleship *Musashi* fell to attack by American carrier-based aircraft.[159] Their story epitomizes the technical successes and operational failures of the whole effort at transforming battlefleet engagement, on the part of both navies.

Naval aviation

To most in the IJN's leadership, aviation itself was expected to be an important but by no means dominant part of "outranging the enemy." Somewhat surprisingly, naval aviation learned a great deal from the fighting in China that was taken, not altogether helpfully, to apply to this role.

Early in the conflict the navy became involved in fighting in Shanghai, an area falling within its sphere of responsibility. The weak and ill-prepared naval forces on the ground had to be rescued by the army, but the IJN took responsibility for air operations in the area, initially using aircraft from carriers operating off shore.[160]

The IJA's air forces were focused on relatively short-range missions in support of ground forces. But China is vast and the naval commander on the scene decided to employ the navy's new long-range Mitsubishi G3M2 long-range twin-engined bombers to strike targets

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[158] David C. Evans and Mark R. Peattie, *Kaigun,* p. 379.

[159] A third ship, *Shinano,* was converted to an aircraft carrier while under construction and subsequently sunk by an American submarine before it ever saw action.

[160] The story of the IJN in China is best told and analyzed in Mark R. Peattie, *Sunburst,* pp. 102-28, on which I have relied for this section.

far inland, flying from bases in Taiwan and Japan. Involving attacks at radii up to 400 nmi, these raids were a remarkable achievement in technical terms. Actual results were meager, however, and gained at considerable cost. Flying unescorted, the lightly-armed and unprotected bombers proved very vulnerable to China's quite limited fighter defenses, despite the G3M2's speed of over 200 kt.[161] And (as was generally to be the case in both Europe and the Pacific in World War II) antiaircraft guns killed about as many aircraft as the fighters.

The IJN, which had no doctrinal position regarding attacks on land targets, was quick to adapt in some ways. In particular, it at once decided that fighter escort was important. The new semi-streamlined Mitsubishi A5M2 fighter was fast enough (just barely) to keep up with the G3M and with a radius of nearly 200 nmi was able to provide effective escort operating from bases seized on China's mainland. The longer-ranged A5M4 was introduced to further extend escort operations.

Recognition of the A5M's limitations in the escort role, however, was a major motivation behind development of a replacement, the A6M – which, with its service designation of Type 0, became famous as the *Zero*.[162] The A6M, which first flew in 1939 and entered combat in China in 1940, was a remarkable aircraft which represented an excellent engineering response to the navy's stringent requirements. As compared with other fighters of the 1000-horsepower generation introduced in various nations in 1939-1940, it had a good turn of speed, top-notch maneuverability, outstanding climb

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[161] René J. Francillon, *Japanese Aircraft of the Pacific War*, p. 357, for performance.

[162] Japanese designation systems for aircraft (and practically everything else) were extremely complex. The Navy gave "type" numbers to aircraft using the final two digits of the year of introduction on the Japanese calendar, 1940 of the Western era being the year 2600 of the Japanese calendar. For years where the last two digits began with a 0, this was suppressed, leaving a single-digit type number. See René J. Francillon, *Japanese Aircraft of the Pacific War*, pp. 46-59 for designation systems.

rate, and unsurpassed range.[163] A notable technology advance was use of "Extra Super Duralumin" for the wing spar structure. This Japanese development was a heat-treated precipitation-hardened aluminum-zinc alloy generally similar to the 75S-T6 (now designated 7075-T6) which was later introduced in the U.S. and widely applied in aircraft structures.[164] It is unlikely that designers in other countries could have met the IJN requirements any better, and many did significantly worse.

Another design influenced by the experience in China was the G3M's successor, the Mitsubishi G4M, which was first flown in 1939 and entered service in 1941. Its two large radial engines provided 3,600 horsepower and it could reach 235 kt. One torpedo or up to 2,200 lb of bombs could be carried internally and it could fly up to 3,270 nmi at 170 kt without bomb load. Defensive armament was strengthened as a result of experience in China, and included a 20 mm cannon to cover the crucial tail sector. A later effort to develop a four-engined long-range heavy bomber, a type which proved very useful to the U.S. forces operating in the vast spaces of the Pacific, did not bear fruit.

But in neither these nor other aircraft did the IJN respond to its experience in China with armor protection or puncture-resistant fuel tanks. Nor was the basic structure designed for ruggedness under fire or ability to absorb damage. These reflected requirements choices based in doctrine rather than design flaws. The overriding

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[163] For a clear account of its design by its young chief designer see Jiro Horikoshi, *Eagles of Mitsubishi: The Story of the Zero Fighter,* Trans. by Shojiro Shindo and Harold N. Wantiez, Seattle: University of Washington Press, 1981. Of the many books about the Zero, the best seems to be Robert C. Mikesh, *Zero,* Osceola, Wisconsin: Motorbooks International Publishers, 1994, but H. P. Willmott, *Zero A6M,* London: Bison Books, 1980 has some useful further information.

[164] Alloys of this class eventually proved vulnerable to a form of failure known as stress corrosion, particularly in marine environments. It is very unlikely that the Japanese knew of this, but it is doubtful that it would have troubled them if they had as fighters of this era almost never had service lives long enough to permit stress corrosion to develop to serious levels.

mission concern was to exact the greatest possible damage in the U.S. battlefleet. In the vast spaces of the Pacific, this meant striking at long range, which made the weight of protection unacceptable. Heavy losses to the attacking aircraft were acceptable so long as they crippled the USN.

Although the engines which powered the A6M and G4M were developed to provide greater power, in essence they represented all but a high-water mark for Japanese powerplants. Of the two major categories of high-powered aero engines in the interwar period – air-cooled radial piston engines and liquid-cooled inline piston engines – Japan elected to concentrate on the radials. The engines used in the A6M and G4M were both twin-row 14-cylinder radials, and good examples of their kind. They had been designed based on technology purchased abroad but incorporated significant locally-introduced improvements. But the next step in radials was to 18-cylinder engines producing 2,000 horsepower and more. These presented problems of vibration and cooling that were considerably more complex than those of the 14-cylinder generation and typically required considerable engineering effort for successful development with the tools then available. Many other aspects of engine development in this class also were troublesome, particularly accessories, induction, and supercharging.[165] Japan had excellent engineers, but it did not have a great many of them. Two major 18-cylinder projects were initiated (one too many, given the limited re-

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[165] United States Strategic Bombing Survey, *Japanese Air Weapons and Tactics,* Washington: Military Analysis Division, 1947, pp. 8-10. For examples of the difficulties encountered in U.S. developments see E. M. Gillum, "'The Beast': Living with the 3350: A History of the How and Why of the Marriage of the B-29 and the R-3350," American Aviation Historical Society, *AAHS Journal.* Vol. 45, No. 3 (Fall 2000), pp. 231-7; Robert E. Johnson, "Why the Boeing B-29 Bomber, And Why the Wright R-3350 Engine?" *AAHS Journal,* Vol. 33, No. 3 (Fall 1988), pp. 174-88; Kimble D. McCutchen, "No Short Days: The Struggle to Develop the R-2800 'Double Wasp' Crankshaft," *AAHS Journal,* Vol. 46, No. 2 (Summer 2001), pp. 124-46; and Graham White, *R-2800: Pratt & Whitney's Dependable Masterpiece,* Warrendale, Pennsylvania: Society of Automotive Engineers, 2001, pp. 21-223.

sources) but neither produced a supply of reliable powerplants by the end of World War II. This made it impossible for the IJN (or IJA) to field aircraft able to contest with high-powered American fighters on equal terms.

Japan was not helped in aircraft and many other fields by its dependence on craft-based production methods which relied on skilled workers who were in short supply and could not be trained rapidly. The problem was further exacerbated by failure to manage manpower effectively in the period of buildup and conflict – essential skilled workers often were drafted into military service and sent to fighting units where their skills were lost.[166] And the all but comical failure of the army and navy to share production resources further dissipated their effect. One simple example of this was ammunition for aircraft guns. The IJN had 7 non-interchangeable sizes of rounds while the IJA had 6 – only one of which was interchangeable with a navy round. By contrast, the U.S. services – certainly no models of cooperation and commonality – had a total of three sizes used by both.[167]

Radar, COMINT, and ASW

Radar was another area in which Japan's limited resources of engineering manpower and manufacturing technique, together with failure to manage what it had effectively, proved crippling. The reports of the delegation Japan sent to Germany in 1940 finally made it clear to the navy (and army) leadership that they were seriously behind in what was a very important field and gave a sudden great impetus to radar development. But despite some significant technical progress, Japanese radar never approached the standard set by the Allies. American forces were surprised to find a simple but reasonably effective IJN ground-based VHF air early warning set when

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[166] Jerome B. Cohen, *Japan's Economy in War and Reconstruction,* Minneapolis: University of Minnesota Press, 1949, pp. 271-352.

[167] United States Strategic Bombing Survey, *Japanese Air Weapons and Tactics,* p. 35.

they invaded Guadalcanal in August of 1942; it had been developed in a one-year crash program. An S-band (3 GHz frequency, 10 cm wavelength) short range surface navigation radar also was an early development, with the prototype deployed at Midway in June of 1942. But Japan was never able to follow up its early magnetron successes with high-power tubes or effective microwave radars.

The IJN's communications intelligence and security efforts faltered badly from 1939 on. The U.S. suddenly introduced a new generation of crypto systems which Japanese cryptologists had no idea how to attack. At the same time, lack of appreciation regarding U.S. cryptological capabilities led the IJN to serious laxity in cryptographic procedures, opening their systems to attack.

The IJN appears to have paid little or no attention to the early stages of the Battle of the Atlantic, and took few steps to strengthen antisubmarine defenses. They did, however, receive some help from Germany on sonar.

Carrier operational doctrine

The China experience seems to have been partly responsible for the IJN's development of a very significant doctrinal innovation in carrier warfare – concentration of carriers in a single formation. In order to mass aircraft for strikes, carriers operated in company off China. Wargaming also suggested that concentration of carriers could be valuable in fleet actions. Ultimately, the IJN shifted from dispersed to concentrated carrier operations just before the outbreak of war. Its "First Air Fleet" of six carriers provided it with the strongest mobile air striking force anywhere and contributed greatly to IJN success in the first six months of war.[168]

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[168] Minoru Genda, "Evolution of Aircraft Carrier Tactics of the Imperial Japanese Navy," in *Air Raid: Pearl Harbor! Recollections of a Day of Infamy*, edited by Paul Stillwell, Annapolis: Naval Institute Press, 1981; and Mark R. Peattie, *Sunburst*, pp. 147-52.

Concentration proved to be a serious vulnerability at the Battle of Midway in June 1942, however. Owing to lack of warning radar, lack of an effective doctrine for employment of fighters in air defense, and weak antiaircraft armament, the concentration of carriers in one formation led to loss of three of them to a single attack by USN dive bombers. This of course was a direct reflection of the IJN's nearly exclusive focus on attack, to the virtual exclusion of defense considerations.

Japanese Army

The IJA's thorough review of its defeat at Nomonhan concluded that the army suffered from many deficiencies in equipment and doctrine in fighting the Soviets, then and for a long time after regarded by the IJA is their most dangerous potential opponent. But little was done, no doubt in large part because the war in China was draining the resources for modernization.[169]

The machinery of ground war

Because the fight at Nomonhan had been against mechanized forces in open terrain, deficiencies in anti-tank capabilities naturally headed the list. Yet little was done to provide IJA infantry with more or more effective anti-tank weapons. Japanese troops would face U.S. armor all but helpless. Not until the very end of the war did the IJA develop simple grenade projectors with armor-piercing shaped charges like the U.S. Bazooka or the German *Panzerfaust,* even though such weapons would have been well within Japan's technical and industrial capabilities.

Two IJA tank regiments were committed at Nomonhan and suffered severe casualties. Recommendations for improved tanks resulted in some progress in design and manufacture of a few hundred improved models. By the time Japanese and U.S. armor clashed head

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[169] Edward J. Drea, *In the Service of the Emperor,* pp. 1-13.

to head in the Philippines in 1944, however, the American tanks were decisively superior.

Japanese artillery performed poorly. The standard 75 mm field gun was inadequate for indirect fire and counterbattery missions, and fired too light a shell for many targets. More modern designs were introduced, including some self-propelled weapons, but production was inadequate to meet needs and most IJA divisions remained armed with odds and ends of artillery, too few in number, too light in caliber, and poorly suited to needs for indirect fire and counterbattery missions. Nothing equivalent to the U.S. fire direction center was developed and control continued to be exercised at the battery level.

Reliance on foot mobility and animal traction handicapped maneuver in the fighting against the Soviets and more motor transport was identified as an urgent need. Only three divisions were even partly motorized, however, and the remainder generally had no more than a few dozen trucks. Glaring deficiencies in combat logistics never were addressed.[170]

The army and air war

Like the IJN, the IJA pursued radar development in the wake of the 1940 mission to Germany. As with the navy, the first effort was a VHF land-based air warning set. Despite the commonality of requirements, no effort was made to coordinate the developments. Along with the IJN, the IJA was generally unsuccessful in developing effective fighter direction capabilities, handicapped by ill-considered air defense organization as well as poor radio communications. A further complicating factor was that army and navy air defense forces frequently operated in the same areas but were entirely

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[170] United States Strategic Bombing Survey, *Effect of Air Action on Japanese Ground Army Logistics,* Washington: Military Analysis Division, Apr 1947, *passim.* While documenting the effects of Allied air attack on army logistics, this makes equally clear the fundamental inadequacies of logistical planning.

incompatible. Like their navy counterparts, the army's radars proved very vulnerable to American jamming.

Until 1943, the IJA remained slightly slower than the IJN to move to the most modern types of aircraft. Its first streamlined monoplane fighter with retracting landing gear was the Nakajima Ki-43. With an engine comparable to that of the A6M Zero, it was generally in the same class. The army's fighter doctrine, however, stressed maneuverability above all other considerations; the navy, while valuing maneuverability highly, was more willing to compromise it for the sake of speed and range. The army Ki-43 had an exceptionally low wing loading and maneuver flaps as well, making it much the most maneuverable fighter of its generation. Its speed was low – less than 270 kt in its initial version – its range was less than that of the Zero (although still substantial), and its armament light. Like the navy, the army was very slow to adopt measures to increase resistance to battle damage. The Ki-43 first flew in January of 1939, but only 40 aircraft were in service in China by December of 1941. The army was faster to develop more modern types thereafter, and fielded several more capable fighters by war's end, whereas the navy remained heavily dependent on the Zero. Nevertheless, even the army fighters fell behind the pace of the U.S. and Britain as the war went on, particularly handicapped by the failure to develop reliable high-powered engines.

Progress in bombers was more rapid, with the second-generation all-metal twin-engined type, the Nakajima Ki-49, contemporaneous with the naval G4M. Moreover, by the outbreak of the Pacific War, the IJA had already initiated development of a still more modern type, the Mitsubishi Ki-67. This medium bomber entered service in October 1944 and was generally comparable to American aircraft of the same class. The later army bombers differed from their naval counterparts in having crew armor, protected fuel tanks, and more rugged construction. Like the navy, the IJA failed to develop a successful heavy bomber.

The army's aviators gained much experience in China and refined their doctrine. However the emphasis on maneuver which seemed to serve well in China would prove to be inadequate against faster

and well armed American fighters, once appropriate doctrine for their use had been developed and instilled. Moreover, the army's doctrine for the use of aviation forces extended only to gaining control of the air and bombing transportation and population centers; using the air force for direct support of troops seemed a foreign notion. Because of this, when the Japanese did gain control of the air over a battlefield, as they did early in World War II, the impact on Allied military operations was less than it might well have been.[171]

Operations

A major lesson not learned by the IJA was the importance of operational and logistical planning. The service's commitment to the spirit of the offensive seemed to leave no room for any thought other than carrying through with a great impetuous rush. Against shocked and unprepared Allied forces in the first months after Pearl Harbor this doctrine worked well for the IJA, even when its forces operated at an overall numerical disadvantage. No doubt this confirmed its validity in the minds of the army's leaders. But outside of China, attempts to re-create these successes against the Allies met with almost uniform disaster after mid 1942.[172]

Naturally, years of fighting the Chinese and, off and on, the Soviets in Northeast Asia did nothing to direct the IJA's thoughts to the problems of fighting the Americans and others in the tropics. As late as November 1941 the service had planned its annual maneuvers as an exercise in a conflict with Soviet forces. In contrast to the U.S. Army, its Japanese counterpart had no jungle warfare doctrine and no doctrine for opposing amphibious assaults.[173] (It was ironic that the U.S. forces which had a well-developed doctrine for countering invasions had very little occasion to exercise it, while the ill-

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[171] A. D. Harvey, "Army Air Force and Navy Air Force: Japanese Aviation and the Opening Phase of the War in the Far East," *War in History*, Vol. 6, No. 2 (1999), pp. 198-203.

[172] Edward J. Drea, *In the Service of the Emperor*, pp. 35, 41, and 69-72.

[173] Ibid., pp. 65-70.

prepared IJA faced landing after landing!) That the Japanese Army often performed well in such operations was testimony to the strength of its basic infantry tactical doctrine and training.

U.S. Navy

In the last years before Pearl Harbor, the USN responded to lessons from its own operational experimentation and wargaming as well as those passed on by its British counterparts. As with the other services these lessons were viewed and understood through the sometimes distorting lens of preconceived doctrine as well as the obscuring fog of unknowns.

Naval aviation

By the late 1930s, plans for a fleet of airship scouts had been dropped, albeit with some reluctance on the part of the Bureau of Aeronautics. Hopes that seaplanes such as the PBY could play an effective attack role had withered in the light of operational experiments.[174]

Few officers were prepared to deny the importance of air forces in naval war, however; the differences were in questions of the degree and nature of the importance and the power of carriers and their aircraft to carry out the mission. There had long been doubt whether carrier-based aircraft could achieve the speed, range, and load-carrying capacity necessary to have a major effect on fleet actions, beyond the very important function of providing long-range spotting and preventing the enemy from spotting against our own forces.

In October 1932 the Martin BM-1 dive bomber became operational, bringing the capability of delivering 1000 lb bombs in nearly vertical dives with good chances of hitting. With up to nearly 800 lb of high

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[174] Mark Allen Campbell, "The Influence of Air Power Upon the Evolution of Battle Doctrine in the U.S. Navy," pp. 148-52.

explosive charge, these weapons could inflict fatal damage to most ships. But they could not penetrate heavily armored decks unless they gained speed by being dropped from high altitudes – the relatively modest diving speed of a dive bomber (250 kt at most) did not impart enough momentum. As the USN had demonstrated to its satisfaction by the late 1930s – if not to that of the Air Corps – bombs dropped from high altitudes had a low probability of hitting a maneuvering ship.[175] No pre-war dive bomber could deliver a 2000 lb bomb (which might fatally damage even a battleship) – indeed the Japanese never did field a dive bomber able to deliver a bomb heavier than 250 kg (550 lb).

Moreover, the range and speed performance of low-powered biplanes severely constrained their utility and striking power. Not until early 1938, when the Vought SB2U-1 and Northrop BT-1 began to come into carrier service, did the service have streamlined monoplane bombers able to reach 200-kt speeds and deliver 1000 lb bombs against targets 250 nmi away, two hours after launch.[176] By that point the USN also had in service the Douglas TBD-1 torpedo bomber, another streamlined monoplane but (owing to the greater weight of the torpedo, over 2000 lb) one having distinctly lower performance than its dive-bomber teammates.[177] Thus it was not until about 1940 that the navy had enough experience with the new force to evaluate its capabilities.

The late 1930s also brought introduction of a number of new weapons and supporting systems which had a significant effect on the effectiveness of carrier striking forces. By no coincidence, introduction of the TBD, the navy's first new torpedo plane in nearly a decade, followed closely on the development of the service's first torpedo designed specifically for air launch, the Mk. 13. No one had

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[175] Thomas Wildenberg, *Destined for Glory: Dive Bombing, Midway, and the Evolution of Carrier Airpower*, Annapolis: Naval Institute Press, 1998, pp. 70-82 and 219-20.

[176] Ray Wagner, *American Combat Planes*, pp. 352-55.

[177] Ibid., pp. 348-50.

any doubt that a torpedo was potentially the most effective weapon for air attack on heavy ships, but the navy was uncertain about weapons which (as it was then thought) must inevitably be restricted to delivery from very low altitudes and very slow speeds, from very short range. After some years spent casting about for alternatives, it was finally decided to proceed with the Mk. 13's much-interrupted development. The service's doubts about the practicality of aerial torpedo attacks seemed all too well borne out by the record of TBDs and Mk. 13s early in the war. But the IJN, which emphasized torpedoes rather than dive bombing, got good results. Later improvements greatly increased the speed and altitude from which the Mk. 13 could be launched and made it into an effective weapon by 1944.[178]

Where IJN doctrine concentrated on the delivery of a single fatal blow at the outset and subordinated all other considerations to maximizing its effectiveness, the USN sought a good measure of combat sustainability as well. This showed up in the alacrity with which the U.S. Navy incorporated armor protection and self-sealing fuel tanks in the light of reports of European combat experience (while most of the IJN's aircraft had little if any protection right to the end of the war). Another manifestation of the same concern appears in the American adoption of a sophisticated radio homing system to aid returning strikes in finding the carrier.[179]

Surface forces

Higher expectations about the effectiveness of carrier strike forces had to be balanced against prospects for improvement in battleships and fleet defenses. The naval armaments treaties had effectively

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[178] E. W. Jolie, *A Brief History of U.S. Navy Torpedo Development*, Newport, Rhode Island: Naval Underwater Systems Center, Newport Laboratory, 1978, pp. 31-6, 42, and 45; and Thomas Wildenberg, *Destined for Glory*, pp. 137, 167-9, 181-2, and 195.

[179] Louis A. Gebhard, *Evolution of Naval Radio-Electronics and Contributions of the Naval Research Laboratory*, Washington: Naval Research Laboratory, 1979, pp. 271-4; and Thomas Wildenberg, *Destined for Glory*, pp. 173-5.

prevented any battleship construction for 15 years and, unlike Japan, America had not embarked on wholesale rebuilding of existing ships. But the expiration of the Washington and first London Treaties at the beginning of 1937, together with the age of the navy's oldest battleships, opened the way for new construction. The navy was still bound by the second London Treaty concluded with Britain as well as Congressional limitations, both imposed in a doomed effort to "lead by example" in arms restraint. But this nevertheless left scope for significant improvements. The two new battleships of the *North Carolina* class provided upgraded protection against torpedoes and bombs, and the four of the immediately succeeding *South Dakota* class managed, within the same overall tonnage, to provide still more. None of these ships could be knocked out by a few hits from aerial bombs or torpedoes. Nor, for that matter, were most of the older battleships regarded as very vulnerable to air attack. While some officers may have erred on the side of optimism with regard to battleship ability to survive hits by bombs and aerial torpedoes, they were not altogether wrong. Actual combat results suggest that in most cases U.S. battleships, which generally were better protected than most, would have survived several hits.[180]

Another factor prompting optimism about the battleship was expectations about air defenses. Some of this of course was prompted by knowledge of progress in radar development and the justifiable expectation that it would aid both defending fighters and antiaircraft (AA) gun defenses. Radio-controlled target aircraft became available late in 1938, permitting the first reasonably realistic live tests of AA gunnery. Results were dismaying.[181] There was initially some tendency to dismiss this as the product of minor, readily correctable faults, or unrealistic test conditions. When the navy was able to study

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[180] Mark Allen Campbell, "The Influence of Air Power Upon the Evolution of Battle Doctrine in the U.S. Navy," pp. 165-8.

[181] Delmar S. Fahrney, "The Birth of Guided Missiles," United States Naval Institute, *Proceedings*, (Dec 1980), pp. 36-7; *Idem*, "The History of Pilotless Aircraft and Guided Missiles," Unpublished ms., n.d. [c.1949-58], pp. 228-73; and Louis A. Gebhard, *Evolution of Naval Radio-Electronics and Contributions of the Naval Research Laboratory*, p. 228.

the experiences of British ships under Axis air attack, however, as well as those of British aircraft in attacking enemy ships, it became clear that the AA problem was far more difficult against modern aircraft than had been supposed.

The navy had depended on what amounted to three layers of AA defense. The outer layer consisted of the 5"/38 dual-purpose gun controlled by an electro-mechanical fire control system that computed target position and movements on the basis of optical angle and range measurements, projected future target position based on current movement, corrected for ship motion using a gyroscopic stable element, calculated the gun orders and fuze settings necessary to direct shells to intersect the plane's path and detonate their charges at the precise moment of intersection, and finally remotely controlled the gun's power drives to match the gun orders. It was the most efficient and effective system of its kind anywhere and no major changes were made to it in the course of the war except to add radar to provide blind firing capability and more accurate ranging.[182] The IJN developed somewhat comparable systems, but the fire control systems lacked gyroscopic stabilization (depending instead on horizon reference provided by operators keeping telescopes trained on the horizon) and automatic follow-up of gun and fuze orders, which no doubt degraded accuracy, particularly under very stressful conditions.[183]

Next came a heavy automatic gun. This role was to have been filled by the new USN-developed 1.1-inch (28 mm) quadruple machine-gun. Reliability of these mounts was initially not very good, but that could be corrected. Not correctable, however, was the weight of its projectile. The one-pound explosive round that had seemed more than adequate against the aircraft of the early 1930s, when the gun

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[182] Norman Friedman, *U.S. Naval Weapons*, pp. 64-7 and 82-4.

[183] U. S. Naval Technical Mission to Japan, *Japanese Anti-Aircraft Fire Control*, O-30, Washington: Department of the Navy, Jan 1946, pp. 1-28 and 42-52.

was designed, was seen to be much too light against the aircraft of the 1940s.[184]

The innermost layer was a lighter machinegun, the standard U.S. .50 cal weapon in a water-cooled hand-trained single mount. This had been recognized to be too light for a long time, but was retained as a final backup.

With the inadequacy of these systems starkly revealed by tests and European war experience, navy response was prompt and vigorous. RADM Ernest J. King – soon to become the commander of the Atlantic Fleet and then, immediately following Pearl Harbor, the Chief of Naval Operations – was appointed in mid 1940 to head an Antiaircraft Defense Board. Responding to the AA board's urgent recommendations, the Swedish Bofors 40 mm and Swiss Oerlikon 20 mm were determined to be the most suitable weapons in their respective classes. The necessary information was obtained, the designs were adapted to permit manufacture in U.S. facilities, and the guns put into production. The Oerlikons began to reach the fleet about the time of Pearl Harbor and the Bofors followed in mid 1942. Tens of thousands of 40 mm and 20 mm guns were mounted before the end of the war.[185] Throughout the war, the IJN relied on a 25 mm gun somewhat inferior to the 1.1-incher.[186]

Control of these weapons presented another challenge. For their power-worked multiple 25 mm mounts the IJN used a system of French origin which depended on operator estimates of target course and attitude. This may have been better than simply "hosing" with tracers, but not by much given the uncertainties in any such es-

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[184] Norman Friedman, *U.S. Naval Weapons,* pp. 74-6; and Buford Rowland and William B. Boyd, *U.S. Navy Bureau of Ordnance in World War II,* Washington: Bureau of Ordnance, U.S. Navy, 1953, p. 219.

[185] Buford Rowland and William B. Boyd, *U.S. Navy Bureau of Ordnance in World War II,* pp. 219-47.

[186] U. S. Naval Technical Mission to Japan, *Japanese Naval Guns and Mounts: Article 2, AA Machine Guns and Mounts,* O-47(N)-2, Washington: Department of the Navy, Feb 1946, pp. 8-14.

timates.[187] In 1940 the USN discovered that Prof. Charles S. Draper of MIT had a concept for using gyros to calculate lead angles based on target apparent motion across the line of sight. Working through the National Defense Research Council (NDRC), newly established to help mobilize the resources of American science for the war effort, the navy sponsored intensive development of a device based on Draper's concept that proved adequate to provide good fire control for guns of all sizes against close-in targets. Wartime production totaled 85,000, with the first systems installed late in 1942.[188]

The worst source of error in the 5-inch gun AA system was range. Two approaches were taken to improve matters. Working again through NDRC the navy in 1940 initiated development of a proximity fuze that would detonate any shell that passed reasonably close to the target at the optimum point for a kill. This involved, in effect, packaging a miniature continuous-wave radar in the nose of shell, a formidable undertaking. The problems were surmounted and the fuze, code-named the VT fuze, went in to production in 1942. First combat kills were achieved early in 1943. Eighty-five million fuzes were produced during the war. While not a panacea, the VT fuze increased the effectiveness of heavier-caliber AA fire by a factor of at least 3:1 overall.[189] While Japanese engineers were familiar with the idea of proximity fuzes and implemented one for bombs (using a very complex optical system), they seem to have regarded an AA fuze as too tough a problem – as indeed it probably would have been relative to the limitations of Japanese technical and industrial resources.

Finally, AA fire by the heavier guns benefited from radar. Optical rangefinding was subject to significant inaccuracies, and particularly

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[187] *Idem, Japanese Anti-Aircraft Fire Control*, pp. 52-6.

[188] Buford Rowland and William B. Boyd, *U.S. Navy Bureau of Ordnance in World War II*, pp. 382-6.

[189] Ralph B. Baldwin, *The Deadly Fuze: Secret Weapon of World War II*, London: Jane's Publishing Co., 1980; Norman Friedman, *U.S. Naval Weapons*, pp. 88-9; and Buford Rowland and William B. Boyd, *U.S. Navy Bureau of Ordnance in World War II*, pp. 271-90.

so against aircraft. Although BUORD greeted radar development rather coolly in the early 1930s – in part due to organizational jealousies – its enthusiasm had quickened by 1938. Primitive AA fire control radars entered service in 1942. In addition to improving ranging, they provided some capability when the target was obscured by darkness or weather.[190]

Radar and sonar

Of course the implications of radar extended well beyond AA gun control. Nevertheless, the navy was very slow to devote substantial resources. In 1939, the Bureau of Engineering, responsible for the navy's electronics development across the board, requested no more than $25,000 for this purpose, exclusive of the salaries of the handful of navy engineers employed in the effort. In response to pleas from NRL, the bureau's chief responded in May of 1940 – well after the outbreak of war in Europe and after a number of British warships had been lost to air attack – that it would be imprudent to press too fast. After some back-channel discussions, the CNO (who had no direct authority over the bureaus at that time) urged the bureau to press forward. Finally in July, after the fall of France and following an organizational shakeup in which the Bureaus of Engineering and Construction and Repair were merged to form the Bureau of Ships, a high-priority and well-funded effort was authorized.[191]

In radar especially the U.S. benefited in many ways from its partnership with Britain. Although the British started somewhat later than NRL, they had devoted substantially greater resources to radar development and by 1941 were ahead in some important aspects of the technology. Moreover, war had brought them much more experience in the practical application of the new sensor. The

[190] L[inwood] S. Howeth, *History of Communications-Electronics in the United States Navy*, pp. 454 and 463-7; and Buford Rowland and William B. Boyd, *U.S. Navy Bureau of Ordnance in World War II*, pp. 423-9.

[191] L[inwood] S. Howeth, *History of Communications-Electronics in the United States Navy*, pp. 458-9.

perience in the practical application of the new sensor. The British technical mission of Sep-Oct 1940 – called the Tizard mission after Sir Henry Tizard, who had prompted the mission and led it – opened important windows for U.S. radar development (as well as in other vital fields of military technology).[192]

The most significant piece from a technology standpoint was the revelation of the brand-new resonant cavity magnetron, the first device capable of generating 10 kW of pulse power at a wavelength of 10 cm (i.e., a frequency of 3 GHz, in S-Band). The U.S. already had identified these microwave frequencies as highly promising for radar and developed good receivers and other subsystems in this band but was behind Japan in transmitter tube development. The Tizard mission reversed this at a stroke and by Jan 1941 – less than a year following the original discovery of the principle of the cavity magnetron in Britain by Boot and Randall – a U.S. 10 cm experimental radar had detected an aircraft.

Since the principle of the cavity magnetron had been independently discovered twice – first in Japan and then in England – there is little reason to doubt that U.S. researchers would have come on it too. But the Tizard mission probably saved the U.S. a minimum a year in the race to get microwave radar into service. Even though Japan had the principle of the cavity magnetron it lagged so far in other aspects of microwave development that the sharing of Britain's work at once catapulted the U.S. into a long lead against Japan. By teaming long-range search radars in the VHF and UHF bands where it already excelled with radars in S-Band and later X-Band (3 cm, 10 GHz) for precision location and control the USN gained a wide range of very valuable capabilities largely denied to the IJN.

Working with Britain also stimulated U.S. development of effective means to make use of radar information. While there had already been work along these lines in America, the British had put more

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[192] E. G. Bowen, "The Tizard Mission to the USA and Canada," in *Radar Development to 1945.*

effort into it and had far more practical experience. The British example was particularly important in air defense and fighter direction. NRL had developed remote radar plan-position indicator (PPI) displays and by siting these in a central space together with plotting and communications facilities the USN was able to quickly and smoothly merge information from all sources to form a coherent picture for tactical decision and resource assignment. Using VHF tactical voice radio systems developed by the navy in the late 1930s, ships were able to promptly cross-tell tracks and coordinate actions. This was a vital step never taken by the IJN.

ASW also benefited from contact with British efforts. Although U.S. sonar transducers and electronics were superior, Britain had better sonar domes and tactical displays and recorders. More significantly, the Royal Navy had developed a much better understanding of how to integrate all of the elements of ASW. Again, this probably saved a year of more of hard lessons. ASW remained a notable IJN weakness throughout the war.

The great benefits gained by the U.S. and Britain from their alliance stand in stark contrast to the meager returns from that between Japan and Nazi Germany.

The treaties – bane *and* boon

Until 1937 the navy had been barred by treaty restrictions from battleship construction. The treaties limited construction of aircraft carriers, but these limits had little effect on USN carrier building before the mid 1930s. The service's first four carriers – USS *Langley, Lexington, Saratoga,* and *Ranger* – all were experiments in one way or another. It was not until 1934 that the navy had a reasonably clear idea of the features needed for a truly satisfactory carrier. The two ships of the *Yorktown* class, laid down in 1934 and completed in 1937-38, closely approximated the navy's view of the best balance for carrier design and proved well suited to the demands of war. At that point, the tonnage allowed to the U.S. for carriers under the treaties had nearly been exhausted and the next ship built, USS *Wasp,* was 25% smaller than was felt to be desirable as a result.

Prior to the lapse of the ban on battleship construction, the treaties probably had aided carrier development and construction by voiding competition for resources; it could not be argued by battleship proponents that new carriers were stealing funds from battleship construction. By 1937, however, the situation had changed. While the Washington Five-Power Treaty had lapsed with Japan's withdrawal, the navy remained bound to its terms as a result of legislation, the Vinson-Trammell Act of 1934. This was the law that provided the authorization for navy shipbuilding. (It did not provide the funds – then as now Congress required separate authorization and appropriation legislation for ships.) It had gone through in the face of stiff opposition from those who feared that armaments stimulated wars, and incorporation of the treaty limits in it had been one of the prices of securing sufficient support to ensure passage. Since its passage, opponents of armaments and overseas involvement had rallied their forces, making the struggle for additional authorization lengthy and difficult.

Thus funds for construction of two battleships (to replace ships becoming "over-age" by treaty definition) were appropriated for Fiscal 1938, but more carriers could not be funded until additional authorization legislation could be passed. With the international situation visibly darkening, President Roosevelt (who had vigorously pursued arms limitation efforts until firmly rebuffed by Japan, thus gaining credibility among many Americans) was successful in his call for added authorizations. The Second Vinson Act, passed early in 1938, permitted construction of two more carriers. The navy responded with a request for a third ship of the *Yorktown* class to provide a near-term reinforcement plus the USS *Essex,* lead ship of the class that would prove to be the backbone of its forces in World War II.

None of this is to say that the navy could not have pressed more vigorously for more carriers sooner. But it is not at all clear whether they would have succeeded, and certainly possible that to have done so could have provoked a damaging backlash. It is difficult to make the case that the service's leaders, for whatever doubts they may

have entertained concerning the carrier's role, were seriously deficient in their efforts to develop carrier forces.

Carrier aircraft development

What about carrier aircraft? As is well known, Japan's carrier aircraft were in some respects advanced over those of the U.S. at war's outbreak. In particular, the USN lagged somewhat in fighters and more in torpedo planes, and its planes in almost every category had less range than their Japanese counterparts. Did the USN pay inadequate attention to development of superior aircraft?

Table 1. First-line carrier-based aircraft, December 1941.

Svc.	Aircraft	Type	Max HP	Best speed	Gross weight (lb)	1st sqdn. svc.	1st proto-type
USN	Grumman F4F-3 "Wildcat"	Fighter	1200	287 kt at 21,100 ft	6,063	Dec 40	Sep 37
IJN	Mitsubishi A6M2 "Zero"	Fighter	940	288 kt at 14,900 ft	5,313	Sep 41	Mar 39
USN	Douglas SBD-3 "Dauntless"	Scout/dive bomber	1000	216 kt at 16,000 ft	9,407	Apr 41	Aug 35
IJN	Aichi D3A1 "Val"	Dive bomber	1000	209 kt at 9,900 ft	8,047	Oct 40	Jan 38
USN	Douglas TBD-1 "Devastator"	Torpedo bomber	900	179 kt at 8,000 ft	9,862	Oct 37	Mar 35
IJN	Nakajima B5N2 "Jill"	Torpedo bomber	1000	204 kt at 11,800 ft	8,378	Mar 41	Jan 37

Table 1 briefly summarizes some of the main data of the most modern aircraft on U.S. and Japanese carrier decks at the time of Pearl Harbor.[193] Several important facts are apparent:

- Within each type, the U.S. aircraft is the heavier by about 15%.
- The U.S. F4F-3 fighter has about 25% more power than the Japanese A6M2, well offsetting its 15% greater weight. The

[193] Sources vary regarding characteristics of these aircraft; I have selected the most plausible and consistent figures based on my own professional experience in aircraft development and performance analysis. The apparent precision of the figures should not be taken literally, as data such as weight and speed performance can vary significantly from sample to sample of a given type of aircraft, and from time to time for the same machine. Some of the dates are estimated.

U.S. SBD-3 dive bomber, although more than 15% heavier than the Japanese D3A1, has the same power. And the Japanese B5N2 torpedo plane has more than 10% more power than the U.S. TBD-1, even though the latter is the heavier by more than 15%.

- All but one of the aircraft versions had first entered squadron service within 14 months of December 1941. The Douglas TBD-1 torpedo bomber, however, had been in service for 50 months.
- The basic designs of the U.S. aircraft, measured by the dates of the first flights of their original prototypes, were older than their Japanese counterparts by an average of 18 months.
- The two Japanese bombers were closely matched in speed, while the U.S. dive bomber was more than 35 knots (20%) faster than its torpedo stablemate, thus making tactical coordination quite difficult.

Not shown in the table is that the A6M2 had a better rate of climb than the F4F-3 – 2,750 ft/min at sea level versus 2,265. As this would suggest, the A6M2 had better turning performance than the heavier F4F-3.

As this makes clear, to some extent the USN was caught between generations of aircraft. New aircraft were in development at the time of Pearl Harbor, but would not see service for several months. As the table also suggests, the USN aircraft had different requirements priorities, reflecting different concepts and doctrine for air warfare.

There is a great deal more that could be said in comparing carrier-based aircraft development in the two countries, but the sum of it for present purposes is

- The U.S. had a distinct advantage in the capabilities of its aircraft engine, accessory, and electronics development teams and manufacturing industry. Japan's deficiencies in these areas – which had not been serious in peacetime when it could li-

cense foreign technology and did not have to manufacture on a large scale – became crippling as the war progressed.

- The skill of aircraft designers in utilizing the available technology to meet military requirements did not differ significantly between the two nations for aircraft designed at comparable dates. However, designers of both nations profited as time went on from experience and from the increasing store of aeronautical engineering knowledge.
- The requirements formulated by the two navies were distinctly different and account for a great deal of the difference between their aircraft.

For the early period of the war, when the differences in technology and manufacture did not weigh very heavily, the divergences between the carrier aircraft of the IJN and USN can best be understood in terms not of design or technology but of doctrine. Even in the case of the torpedo bombers (where the TBD's prototype had first flown more than 20 months before the B5N's and the current TBD-1 model had been introduced more than 40 months earlier than the B5N2) doctrine played an important role – no doubt the USN would have devoted more effort to a modern torpedo plane had it placed the same emphasis on the aerial torpedo as a weapon that the IJN did. As can be seen from the fact that USN dive bombers carried 1000 lb weapons while IJN dive bombers were limited to 550 lb bombs, the USN counted relatively more heavily on this mode of attack.

It is unlikely that the fighter pilots of either service would have been happy to be equipped with the aircraft of the other. Japanese dive bomber pilots might very well have preferred the SBD to their own D3A, however, and it is likely that the USN's torpedo bomber crews would have been glad to turn in their TBDs for B5N2s. On the other hand, it is not at all clear that early combat results would have changed markedly had the two sides exchanged aircraft.

Tactical air operations

From the USN's standpoint, the outcomes of the actions by carrier-based and land-based carrier-type aircraft in the first year of the war were good but by no means outstanding. The results of torpedo attacks were generally disappointing (although there were exceptions). The costs of these attacks were increased by the poor performance of the TBD, but the principal problem was the deficiencies of the Mk. 13 torpedo. Dive bombing results were much better, but it appears that USN dive bombers did not achieve as large a percentage of hits as did their IJN counterparts. This may be due to the very high state of training, strengthened by combat experience in China, of IJN first-line bomber crews.

The unexpectedly high performance of the A6M Zero, together with the high proficiency of its pilots, led to some alarm among USN aviators early in the war and demands for improved aircraft. While USN fighter training before the war had not been as intense as the IJN's and its units lacked the IJN's combat experience, however, early action did demonstrate that U.S. naval fighter pilots had good skills. Their leaders quickly developed tactical doctrine to optimize utilization of the F4F's strengths against the A6M's weaknesses, with good results. The F4F lacked the performance advantage and range for effective offensive counter-air (OCA) operations, but proved quite effective in defensive counter-air (DCA) against A6Ms attempting to fulfill OCA roles.

DCA was weakened by lack of sufficient fighters on board the carriers as well as doctrinal inadequacies regarding their employment in DCA. Great faith had been placed in radar as an aid to defense, but effective doctrine for its employment had not been thoroughly developed and practiced. Because the early radars gave very coarse bearing information, only vague indication of altitude, no way of telling friend from foe, little information concerning raid size, and very poor low altitude coverage, it was by no means simple to employ them effectively.[194] Of course radar was very new in the fleet

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[194] Norman Friedman, *U.S. Naval Weapons,* pp. 89-92.

and there was little time to gain experience on which to base doctrine. But application of operations analysis could have helped significantly, as British experience already had demonstrated.

Guided weapons

One interesting and somewhat disappointing sidelight to USN aviation development was guided missiles. Many nations developed remotely controlled boats, ships, and aircraft to serve as targets between the wars, but the USN was among the first to mount a serious effort to extend this to guided missiles. Drone development had sprung from an effort by the Bureau of Aeronautics (BUAER) with NRL developing a practical and robust radio control system. Television equipment was available by 1940 and NRL developed a link for relaying the signal from a camera in a drone to a distant control aircraft. With this it was demonstrated in live tests early in 1942 that it was possible to hit a maneuvering target ship with a torpedo launched from a drone at very close range or with drone crashing into it. An "assault drone" was quickly developed and available for combat use by 1944. Opposition by the senior aviator in the Pacific, then-VADM Towers, limited operations to a minor (albeit successful) demonstration. He advanced various reasons for his opposition but it is difficult to avoid the impression that in large part he was simply determined not to encourage a potential competitor to the newly-ascendant naval aviation.[195] BUAER efforts to develop an air-launched land-attack TV-guided missile – presumably more congenial to aviators like Towers – did not bear fruit until after the war.[196]

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[195] As will be discussed below, there is reason to doubt that the BUAER work on guided missiles was known to NDRC groups working in the area. If true, this would imply that BUAER had not disclosed its work to the Joint New Weapons Committee which oversaw all U.S. activities in guided weapons, as it was supposed to. This in turn suggests some pretty strong internal institutional resistance.

[196] Delmar S. Fahrney, "The Birth of Guided Missiles," pp. 54-60; *idem*, "The Genesis of the Cruise Missile." *Astronautics & Aeronautics.* (Jan 1982), 34-9 and 53; Norman Friedman, *U.S. Naval Weapons,* pp. 215-6; and Louis

Interestingly, while BUAER was developing surface-to-surface assault drones, its sibling rival BUORD was working with NDRC to develop air-launched antiship missiles, Robin, Moth, Pelican and Bat. The BUORD and NDRC histories say nothing about the BUAER program and there is circumstantial evidence that they knew nothing about it. There is a strong suggestion that one of the projects which failed, the TV-guided Robin, fell victim to problems that BUAER had already solved.[197]

Bat was a particularly fascinating weapon, a 1000 lb glide bomb with an entirely self-contained radar homing system. Unsurprisingly, this remarkably sophisticated system had severe problems, but it was put into operation with land-based patrol aircraft in 1945 and achieved some success in ship attacks, the first fully autonomous guided missile ever successfully employed in combat.[198]

Surface doctrine, operations, and weapons

The USN's surface forces also were handicapped by poor doctrine, particularly for night operations. The Japanese emphasis on night operations had been apparent in the Russo-Japanese War and was well known, although the details of IJN night doctrine were not. USN exercises and experiments between the wars had given reason for concern about night action, and it was well known that the British had lost a significant opportunity at Jutland due to weak preparations for night combat. Nevertheless, little was done.

A. Gebhard, *Evolution of Naval Radio-Electronics and Contributions of the Naval Research Laboratory*, p. 227-32.

[197] Buford Rowland and William B. Boyd, *U.S. Navy Bureau of Ordnance in World War II*, p. 341; and Office of Scientific Research and Development, National Defense Research Committee Division 5, *Guided Missiles and Techniques*, Summary Technical Report of Division 5, NDRC, Vol. 1, Washington: 1946, pp. 1-2.

[198] Norman Friedman, *U.S. Naval Weapons*, p. 202; and Buford Rowland and William B. Boyd, *U.S. Navy Bureau of Ordnance in World War II*, pp. 340-4.

Again, much faith was placed in radar while failing to develop effective means for its employment. In fact, few surface combatants other than battleships had radar at war's outbreak. Poor bearing accuracy, poor resolution of multiple targets, and lack of target identification made it difficult to extract a clear tactical picture from the early radars and rendered them largely ineffective for fire control. Only after severe early defeats in night actions around Guadalcanal in 1942 and early 1943 was the need for effective combat information organization recognized and acted upon.

Surface combat doctrine at night as in daylight emphasized tightly coordinated and centrally directed gun action. In essence, light forces fighting at night were expected to apply the same doctrine as heavy forces in daylight. Not until 1943, after multiple painful losses, was it recognized that the circumstances were entirely different and called for a distinctly different tactical doctrine, emphasizing flexible independent action and early torpedo attacks.

The matériel of the surface forces in on the whole proved to be good. Even though USN combatants were generally significantly smaller than their Japanese counterparts (in part because the IJN had taken a very relaxed attitude toward its treaty obligations regarding warship sizes) they gave good accounts of themselves when employed well. The Mk. 15 torpedoes of U.S. destroyers were not the equal of the much larger Japanese Type 93 oxygen torpedoes, of course, but were adequate when employed well. If the two sides had interchanged torpedo types it is unlikely that the combat results would have been very different.[199]

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[199] This somewhat glosses over the question of the Mk. 15's exploder. It was essentially identical to that of the submarines' Mk. 14 torpedo, and presumably suffered the same problems. How much this compromised the results in the surface actions cannot really be assessed very well on the basis of existing evidence.

Logistical support for surface forces

Some senior naval officers pressed for construction of naval auxiliary ships in the 1930s and the navy did request them several times. The political impetus was lacking, however, and none were built for several years.[200] One argument was that the navy could convert merchant ships rapidly in time of emergency. This of course depended on the state of the merchant marine and mercantile shipbuilding – which was parlous. The Merchant Marine Act of 1928 provided a mail subsidy program to stimulate merchant shipbuilding, but its effects wore off early in the 1930s. The Roosevelt administration struggled to square the circle of providing work for the masses of unemployed while practicing strict governmental economy in a period of depressed tax revenues. Eventually the Merchant Marine Act of 1936 established the independent Maritime Commission, empowered to subsidize the merchant marine in various ways in an effort to offset the American cost disadvantage relative to foreign builders and operators. Naval personnel were heavily involved in the commission's direction and operation, and it soon began to bring out ships that had the characteristics desirable to permit naval use.[201]

Maritime Commission ships would provide the mainstay of the naval auxiliary and amphibious transport fleets in World War II. Naturally, it is very difficult to disentangle the motives behind the Merchant Marine Act of 1936 and the subsequent Maritime Commission building program, but it is clear that national defense was a prominent justification. It was an important step – but it did not differ in principle from what Japan was doing with its own merchant ship subsidy programs.

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[200] John C. Walter, "The Navy Department and the Campaign for Expanded Appropriations, 1933-1938," Ph.D. diss., University of Maine, Orono, Maine, 1972, pp. 175-372, *passim.*

[201] Thomas C. Hone, "Naval Reconstitution, Surge, and Mobilization: Once and Future," *Naval War College Review,* Vol. 47, No. 3 (Summer 1994), pp. 67-85; and Robert H. Levine, "The Politics of American Naval Rearmament, 1930-1938," Ph.D. diss., Harvard University, Cambridge, 1972, pp. 53-61, 147, 469-78.

The navy also made steps toward development of underway replenishment and mobile base forces. The British, Japanese and U.S. navies all had developed methods for refueling ships underway at sea before the war. In both the USN and IJN it appears that destroyers were generally fueled while alongside the replenishment vessel. These methods involved light rigs and close ship spacing and were regarded as too dangerous for refueling heavier ships. Since cruisers and battleships had large fuel capacities this was not too serious. For those occasions when it was necessary to refuel them, methods were developed involving passing a towline with attached hose between oiler[202] and warship. This could be done only at slow speeds and the long, single hose restricted the rate at which fuel could be transferred.

In the fleet exercises of the 1930s the USN quickly learned that, large capacity notwithstanding, carriers could quickly deplete their fuel when conducting combat operations. By the end of 1938, the fleet was addressing the problem of refueling carriers underway. Building on earlier experience with destroyers, alongside methods were developed and tested out with good results. Heavier rigs and multiple hoses allowed fuel to be passed rapidly at safe separations. A workable basic technique was well established by the outbreak of war.[203]

Wartime experience quickly led to improvements. Oilers passed small quantities of cargo – mail, fresh produce, critical spare parts – using light rigs while alongside. Only in the last year of the war were the techniques of transferring large quantities of ordnance and stores underway perfected. But fuel was the most limiting quantity, and the development of rapid alongside methods for refueling at sea was a critical innovation. Although simple in concept, the skills

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[202] In USN terminology an *oiler* is a tankship intended for use in refueling at sea, whereas a *tanker* is an otherwise similar vessel engaged in point-to-point shipment. Tankers generally can be adapted as oilers with the addition of suitable deck equipment and rigs.

[203] Thomas Wildenberg, "Chester Nimitz and the Development of Fueling at Sea," *Naval War College Review*, Vol. 46, No. 4 (Autumn 1993), pp. 52-62.

and equipment involved were sophisticated and it took a long time for other navies to develop them.

Submarine forces

U.S. submarine forces present a very mixed picture. The USN submarine doctrine, which had emphasized submarine participation in fleet action, was abandoned at once as the mission concept shifted to commerce destruction. This left commanders to improvise appropriate implementing doctrine. The difficulties this presented were surmounted with quite remarkable speed and effectiveness. It appears that reports of German doctrine, particularly regarding night surface attacks, were put to good use. The submarines themselves proved very well adapted to the new mission, with a few relatively minor refinements. (Of course the IJN's protracted neglect of ASW helped a great deal as well.)

The story of the force's torpedoes is dismal and well known. The Mk. 14 torpedo was fundamentally sound but was severely handicapped by deficiencies in depth-keeping, magnetic influence fuzing, and contact fuzing. All three of the interwar U.S. torpedo developments were conducted by the U.S. Naval Torpedo Station, Newport, Rhode Island, whose exclusive rights to USN torpedoes were zealously guarded by local Congressional representatives. None of the three was as good as it could and should have been, but the failings of the Mk. 14 were particularly egregious. The cause was inadequate engineering analysis and design, compounded by inadequate engineering development and test, compounded by virtual lack of operational test.[204] It is reasonable to expect that had the Torpedo Station and its BUORD parent been more subject to open competition and/or independent oversight, results would have been better.

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[204] Frederick J. Milford, "[U.S. Navy Torpedoes, Part Two:] The Great Torpedo Scandal, 1941-43," *The Submarine Review*, (Oct 1996), pp. 81-93.

COMINT

In the navy, as in the army, the code-breakers gained control over code-making. It was a brilliant move. Knowing exactly how seemingly trivial faults could provide a purchase for prying apart a crypto system's secrets, army and navy cryptologists proceeded to build a truly unbreakable machine cipher (usually called SIGABA, although known better as ECM in the navy) for joint use. The navy cryptologists also produced a convenient manual strip cipher system for lower-level naval use. It is doubtful whether SIGABA could be broken even today and the strip cipher in practice proved very resistant.[205]

The navy slowly developed and integrated the five legs of communications intelligence (COMINT): intercept, cryptanalysis, language analysis, traffic analysis, and direction finding (DF). DF was the last to fall in place with development and deployment of an NRL-developed manually-trained twin-dipole interferometric (Adcock-type) high-frequency DF (HFDF) system late in the 1930s.[206] These were supplemented with crossed Adcocks feeding Watson-Watt cathode-ray-tube instantaneous goniometers to provide DF of short-duration signals.[207] A small nucleus of capable intercept operators and traffic analysts had been built up, in significant measure through local initiative within the navy's communications community.[208] Development of Japanese language analysts, however, was very slow due to misplaced priorities. Army development of a capa-

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[205] Stephen J. Kelley, *Big Machines*, pp. 108-53 and 216-27.

[206] Louis A. Gebhard, *Evolution of Naval Radio-Electronics and Contributions of the Naval Research Laboratory*, pp. 307-8.

[207] The loops used for DF of lower-frequency signals had proven to give unsatisfactory accuracy at HF owing to the effects of skywave paths (i.e., those involving refraction by the ionosphere) in distorting polarization information. The Wullenweber circularly-disposed array antenna (CDAA), long familiar at U.S. intercept sites, was developed in World War II in Germany and perfected and adopted by the U.S. after the war.

[208] Duane L. Whitlock, "The Silent War Against the Japanese Navy," *Naval War College Review*, Vol. 48, No. 4 (Autumn 1995), pp. 43-52.

bility to read the high-level Japanese diplomatic cipher system early in 1941 (as described above) drew navy COMINT effort away from IJN targets, with unfortunate results in delaying solution of the latest changes in IJN codes. Moreover, the navy lacked a sound operational intelligence structure within which it could evaluate and integrate the valuable information provided by COMINT.[209]

U.S. Marine Corps and amphibious warfare

The USMC had always taken seriously its "first to fight" tag line and worked hard at unit training and preparation. As a force, however, its capabilities were not very impressive in the 1930s. Marines were few in number and lightly armed and equipped. They had essentially no unique weapons or equipment, but utilized those developed for the army and navy.

Experience and doctrine

The Marine Corps was unique among U.S. forces in having significant combat experience between the world wars. Before World War I, a mixture of strategic, economic, and ideological motives had led President Woodrow Wilson to seize control of the governments of both of the nations of the Caribbean island of Hispaniola, Haiti and Dominica. A USMC brigade furnished the "pacification" force, and in each case became the de facto government. Unsurprisingly, the pacification campaigns stimulated at least as much unrest as they quieted, and the marines faced periodic small-unit combat. The last Marine Corps forces left Hispaniola in 1934. Their two decades there had brought much frustration, but also significant experience

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[209] Frederick D. Parker, *Pearl Harbor Revisited: United States Navy Communications Intelligence, 1924-1941*, United States Cryptologic History, Series IV, World War II. Vol. 5, Fort George G. Meade, Maryland: Center for Cryptologic History, National Security Agency, 1993.

in conditions not altogether unlike some they would encounter in the South Pacific.[210]

Another pacification campaign took place in Nicaragua between 1926 and 1933. Its frustrations and results (or lack of results) were broadly like those of the Hispaniola efforts. Again it provided combat experience, including some in the jungles of Eastern Nicaragua, and brought to the fore some of the men who would be major leaders of the USMC in World War II.[211]

Marine doctrine for ground combat differed subtly from that of the army. Both counted on infantry, but Marine Corps doctrine envisioned a lighter infantry force which relied less on artillery. In this, of course, the marines were closer in spirit to the IJA. But they did not go to the extremes of the Japanese, and looked for firepower wherever they could find it. And their experiences in the Caribbean and Nicaragua, where engagements could erupt suddenly and at close range, had made them acutely sensitive to the need for light automatic weapons for the infantry.

One place the USMC found fire support was in the air. Aircraft flown by Marine Corps aviators had proven useful in operations against irregulars in Hispaniola. But it was in the somewhat later operations in Nicaragua that the value of airborne firepower – as well as air-delivered logistics – first came into focus. The Corps well recognized that the situation was not typical of real war in that there was no air opposition and only the lightest of ground fire, but it nevertheless provided valuable lessons in close support and ground-air cooperation.[212]

As carriers entered the fleet in the 1930s Marine Corps squadrons took their places in the air groups in some cases, much as marine detachments manned guns aboard battleships. The marine aviators

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[210] Allan R. Millett, *Semper Fideles*, pp. 178-211.

[211] *Ibid.*, pp. 236-63.

[212] Richard P. Hallion, *Strike from the Sky: The History of Battlefield Air Attack, 1911-1945*, Washington: Smithsonian Institution Press, 1989, pp. 71-5.

grumbled about this diversion from service with Marine Corps ground units.[213] Yet in the war to come, USN and USMC air squadrons would prove able to operate flexibly from carrier decks and primitive land bases, jumping swiftly from one to another as operational needs changed. It was to be a very important capability, especially in the early days when air power of all kinds was stretched thin. I have seen nothing to suggest that this was in the minds of naval aviators in the 1930s, but what they did served to lay the groundwork.

The other major source of firepower for Marine Corps forces, particularly in the critical phases of an amphibious assault, was naval gunfire. Unfortunately, if unsurprisingly, the Navy did not devote anything like the attention to supporting assaults that the Marine Corps did to conducting them. Limited, safety-constrained tests and shallow thinking produced a faulty doctrine which envisioned relying on intense but brief suppressive barrages rather than systematic destruction of defenses. The lessons not learned in peace would be taught at far greater cost by war.[214]

With the close-out of involvement in Caribbean and Central American pacification campaigns and modest increases in funding, the naval services were able to resume amphibious exercises in 1934. These helped to clarify many of the complexities of assault operations and prompted some advances in thinking about logistics and fire support.[215]

Despite the lacunae, the Marine Corps and to a lesser extent the Navy entered World War II with what would prove to be a fundamentally sound basis for amphibious assault doctrine. It was a remarkable transformation, achieved at very slight cost, which would prove every bit as crucial as marines had supposed it to be.

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[213] Allan R. Millett, *Semper Fideles*, pp. 334-5.

[214] *Ibid.*, pp. 332-3 and 337-8.

[215] *Ibid.*, pp. 337-40.

In form there was another initiative by the USMC: formation of defense battalions specializing in protection of American bases and possessions. In fact this was at least in large measure a ploy to build up forces without appearing unacceptably "offensive" in a United States whose public still entertained strong reservations about any military action other than homeland defense. While a Marine defense battalion stood ready to defend Midway and elements of another gave superior Japanese forces a very difficult time before they conquered Wake Island, the greatest service of these units was in offensive action.[216]

Amphibious matériel

Lack of resources inevitably hampered development of matériel for amphibious assault even more than it had that of doctrine. The beaches of the Central Pacific islands were either exposed to the full force of oceanic waves or else sheltered by coral reefs. Either case presented serious obstacles. The only amelioration was that, lying at fairly low latitudes, they were out of the major storm belts. They were of course exposed to typhoons, but these were infrequent and fairly calm weather prevailed at other times.

The exercises of the 1920s served to demonstrate the unsuitability of ordinary ships' boats for amphibious assault. They continued to be used in those of the 1930s, despite this recognition, simply for lack of anything better. At Marine Corps prompting, the Navy Department's Bureau of Construction and Repair (BUC&R) devoted some effort to the search for suitable landing craft.[217] Many concepts

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[216] A[lexander] A[rcher] Vandegrift, and Robert B. Asprey, *Once a Marine: The Memoirs of General A. A. Vandegrift, United States Marine Corps,* New York: W. W. Norton & Co., 1964; Quantico, Virginia: Marine Corps Association, and New York: Ballantine Books, 1982, pp. 91-92.

[217] It is usual to call the bureaus "Navy" organizations, but this is somewhat misleading in the context of relations between the Navy and Marine Corps. In this period, the bureaus reported to the Secretary of the Navy and did not answer to either the Commander-in-Chief, U.S. Fleet or the CNO. They were headed and predominantly staffed by Navy officers and

were tried and found not to be very satisfactory. Finally, after knocking on a number of doors, a persistent Louisiana boat designer/builder named Andrew J. Higgins managed to get a trial of his "Eureka" hard-chine, shallow-draft craft, equipped with a skeg to ease beaching and retracting. After some modifications it proved to work well. The one remaining problem was getting troops from the boat to the beach by some swifter and less exposed method than jumping over the gunwales. Marine Lieutenant (later Lt Gen) Victor Krulak, serving in China, had noted and photographed IJA landing craft with small bow ramps. Higgins was asked for a comparable ramp and instead fitted his boat with a larger one that allowed not only rapid debarkation of troops but carriage of vehicles. This became the basis for the successful and long-lived LCVP and LCM classes of landing craft.[218] During the war, the U.S. built 43,374 of these craft.[219]

Higgins boats could get troops and matériel to open beaches, but what about beaches guarded by reefs? What about swamps? An admiral, seeing a story in a news magazine, brought to marine attention the development of an amphibious tractor by an engineer seeking mobility in Florida swamps. The Corps did not need any added encouragement. They had long been seeking workable tracked amphibious vehicles and moved to outfit themselves with what proved

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thus no doubt tended to be more responsive to strictly Navy concerns, but were separate from the operational Navy as such and pursued their own policy agendas. The Marine Corps and operational Navy alike could only request and not demand of the bureaus, save to the extent that they could gain Secretarial sanction.

[218] Norman Friedman, *U.S. Amphibious Ships and Craft: An Illustrated Design History*, Annapolis: Naval Institute Press, 2002, pp. 67-99.

[219] Bureau of Ships, Historical Section, *An Administrative History of the Bureau of Ships During World War II*, 4 volumes, "First draft historical narrative," 8 Aug 1952, Vol. 3, p. 202.

to be a key item of matériel for amphibious assault.[220] A total of 18,621 were built in the war to follow.[221]

While the Higgins craft and amtracks provided satisfactory solutions to getting Marine Corps (or Army) forces ashore, there was the question of how both they and the forces were to be transported to the scene. The general presumption was that conversions of passenger liners and cargo vessels would serve. This did not take adequate account either of the specialized needs of amphibious operations or the scale on which they developed.

Once again, the alliance with Britain proved useful. The British, stung by the disastrous experience at Gallipoli in World War I, had paid relatively little attention to amphibious assault between the wars. But once Hitler had conquered France, it was apparent that only amphibious assault could permit British forces ever to attack Germany in force. The British developed the technique of commando raids, and looked to a massive assault in the future. They quickly recognized the merits of the Higgins craft and their orders helped Higgins stay in business at a critical time. But they also needed amphibious shipping and they pressed the U.S. for help, while providing both important design ideas and valuable lessons from early operations. While Britain and U.S. forces in Europe competed with the Pacific theater for amphibious ships and craft, the program stimulated by needs in Europe worked very much to the advantage of amphibious capabilities in the Pacific as well.[222]

Two of the most notable products of the American-British collaboration were the tank landing ship (LST) and the dock landing ship (LSD), with its submersible well deck. During the war, the U.S. produced 1043 LSTs, including 513 in the single year of 1944. Produc-

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[220] *Ibid.*, pp. 99-100; Victor J. Croizat, *Across the Reef: The Amphibious Tracked Vehicle at War*, London: Arms and Armour Press, 1989, pp. 31-4.

[221] Bureau of Ships, Historical Section, *An Administrative History of the Bureau of Ships During World War II*, Vol. 3, p. 202.

[222] Norman Friedman, *U.S. Amphibious Ships and Craft*, pp. 103-48.

tion of the LSDs was slower owing to their complexity – 25 were produced, some of them too late to get into action.[223]

Armor-piercing projectiles for battling armored ships were of limited value against most shore targets. Just before the war the CNO called for development of high-capacity rounds for all the guns likely to used in shore bombardment (except for those which already had suitable rounds). By strenuous effort, the Bureau of Ordnance was able to equip most ships with HC rounds in time to support landings in 1942 and beyond. These differed from earlier "bombardment" rounds in having somewhat heavier cases to give them the ability to penetrate and destroy light fortifications as well as producing blast and fragment damage. Huge numbers were used in the war – more than half a million rounds in the final assault at Okinawa.[224]

Many further important matériel developments took place during the war itself. Just how critical amphibious warfare was to the prosecution of World War II, in the Atlantic as well as the Pacific, can be gauged from the priorities accorded to construction. On 4 July 1942 the Bureau of Ships was directed to give landing craft and landing ships its utmost priority, ahead of carriers, destroyers, battleships, and everything else. They stayed in that spot until 11 August 1944, when they gave way to the larger amphibious shipping needed for the final invasions in the Western Pacific.[225]

U.S. Army

The U.S. Army awoke from its slumbers with an awful start at news of the fall of France before the *Blitzkrieg*. The French Army had

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[223] Bureau of Ships, Historical Section, *An Administrative History of the Bureau of Ships During World War II*, Vol. 3, p. 201.

[224] Buford Rowland and William B. Boyd, *U.S. Navy Bureau of Ordnance in World War II*, pp. 59-62.

[225] Bureau of Ships, Historical Section, An Administrative History of the Bureau of Ships During World War II, Vol. 3, pp. 179-80.

been regarded as strong and capable, and certainly a match for the Germans in defending its own territory. To see it completely defeated in so short a time was a shock. In general the army made good use of the 18 months that remained to it before it too became involved in war, but found that this was not enough time to generate forces in the quantity or quality needed.

A major effort was put into development of armored forces, which is largely peripheral to our theme. Transformation of field artillery was in some ways even more remarkable, however. The army at last decided on completely motorized traction and settled on a 105 mm howitzer to replace the 75 mm gun as the backbone of divisional artillery. Even more significantly, the fire direction concepts developed at the artillery school were adopted as the fire direction center (FDC). This entailed shifting primary responsibility for fire direction and gun order calculation from the firing battery to the battalion, and allowed prompt concentration of the fires of a complete battalion or even a whole division's artillery on a new target. It was a major innovation which, together with good matériel, made U.S. artillery the most effective in the world and the backbone of ground combat.

It's a jungle out there

The circumstances of the Pacific War often did not allow full utilization of artillery, however, and lighter and more maneuverable (but not less powerful) artillery would have been especially valuable. The army had developed a 1,300 lb 75 mm pack howitzer which could be broken down into individual loads none of which was heavier than 350 lb. This was widely used in the Pacific, but its 15 lb projectiles and 10,000 yard range were inadequate for many needs. Nevertheless, artillery did play a very important role in U.S. success on the ground in the Pacific.[226]

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[226] Eric M. Bergerud, *Touched with Fire: The Land War in the South Pacific*, New York: Viking, 1996, pp. 328-9; Kevin J. Dougherty, "WWII: Artillery in a Jungle Environment," *Field Artillery*, (August 1994), pp. 22-5; and Con-

Light mortars of 60 mm and 81 mm calibers had been developed before the war and were valued as sources of very portable indirect fire. Their effectiveness was severely reduced by heavy vegetation cover, however, a situation often encountered. The army's Chemical Warfare Service had developed a 4.2 in (107 mm) mortar for delivery of white phosphorous, smoke and chemical munitions. By early 1942 the CWS recognized that high-explosive ammunition would do a great deal for the weapon's utility and added this capability. This bit of military entrepreneurship turned the CWS into a significant combat arm in a conflict with no chemical warfare. As the mortar fired a very potent round with good foliage penetration, yet at 350 lb was far more portable than any artillery piece, it was very useful in the Pacific (as it was also in many areas in Europe). However, it did not reach the theater until the end of 1943.[227]

Artillery and mortars were of course best suited for indirect fire. But there was also a need for heavy direct-fire weapons to operate in close support of infantry. This need, which had long been recognized, was intended to be met by the 37 mm gun, adapted from an early German anti-tank weapon. It fired a 1.6 lb high-explosive round at velocities up to 2,600 ft/s or a 1.9 lb armor piercing round at up to 2,900 ft/s. While this gave some valuable service in the Pacific, its weight of nearly 1,000 lb and the bulk of its wheeled carriage made it unsuitable for many circumstances. Nor was its destructive effect very adequate for many targets.[228]

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stance McLaughlin Green, Harry C. Thomson, and Peter C. Roots, *The Ordnance Department: Planning Munitions for War,* pp.180-2.

[227] Eric M. Bergerud, *Touched with Fire,* pp. 314-8; and Leo P. Brophy, Wyndham D. Miles, and Rexmond C. Cochrane, *The Chemical Warfare Service: From Laboratory to Field,* United States Army in World War II: The Technical Services, Washington: Office of the Chief of Military History, Department of the Army, 1959, chapter VI.

[228] Constance McLaughlin Green, Harry C. Thomson, and Peter C. Roots, *The Ordnance Department: Planning Munitions for War,* pp. 182-6; William O. Odom, *After the Trenches,* pp. 153-4; and Ordnance Department, *Catalogue of Standard Ordnance Items,* 3 vols., Washington: War Department, 1944, Vol. 2, pp. 156-7.

Various expedients were improvised in the Pacific, including a number of adaptations of light automatic antiaircraft guns. Flame throwers met some needs as did rifle-launched grenades and shoulder-fired "Bazooka" rockets with shaped charges. Late in the war, recoilless rifles in 57 mm and 75 mm reached service and were found very useful for blasting Japanese field fortifications. None of these weapons employed any new or previously unknown principles, but it took a year or more to rush each to the front, and most were found to have significant initial defects in the grueling environment of jungle and amphibious warfare.[229]

After a very protracted development, the army had started rearming its troops with the first semiautomatic rifle to see wide service, the M1 "Garand" (after its principal designer). Later adopted also by the Marine Corps, this proved to be a very satisfactory weapon which significantly increased firepower. However, the army (along with the marines) had neglected development of a squad-level light machine gun, having a doctrinal preference for putting firepower in the hands of the individual rifleman. Its place was only partly filled by the M1918 Browning Automatic Rifle or BAR. High-volume firepower was particularly important in jungle warfare, where meeting engagements could develop at very short ranges or troops might have to shoot their way out of an close-range ambush. Submachine guns were very useful in these cases, where they provided highly portable volume fire and their lack of range was irrelevant – marines seemed particularly to value them. But it took until 1943 to get

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[229] Eric M. Bergerud, *Touched with Fire,* pp. 301 and 372-4; Constance McLaughlin Green, Harry C. Thomson, and Peter C. Roots, *The Ordnance Department: Planning Munitions for War,* pp. 328-31, and 368-371; and Brooks E. Kleber and Dale Birdsell, *The Chemical Warfare Service: Chemicals in Combat,* United States Army in World War II: The Technical Services, Washington: Office of the Chief of Military History, Department of the Army, 1966, pp. 535-91.

a truly satisfactory submachine gun, the M3, into the hands of the troops.[230]

The firepower of U.S. infantry and supporting units shocked the Japanese when they first encountered it and contributed much to success on the ground. But much of it was the product of hasty improvisation and adaptation rather than foresighted planning and development.

The deficiencies in preparation for the Pacific War extended beyond weapons to include virtually every type of matériel. Ammunition, vehicles, communications gear, rations, clothing, medical supplies, and many other things proved in various degrees to be inadequate to meet the climate and circumstances of jungle, island, and amphibious warfare. Some of this was unavoidable, of course, but some was a result of doctrine. The army developed matériel to meet doctrinal needs, and in the main doctrine provided little guidance with respect to the war to come.

This was despite the fact that the army had extensive experience in jungle operations and combat, and did develop specific doctrine for jungle warfare. It had fought against rebels and bandits in the Philippines early in the century and had stationed and exercised troops in the islands as well as the Panama Canal Zone since then. On the eve of World War II it published its first doctrinal manual on jungle warfare and included a section on jungle warfare in its top-level warfighting doctrine publication.[231] Their terminology and focus makes it clear that these doctrinal publications reflected army experience in the Philippines, and they provided generally realistic guidance. But while the army had long published extensive doctrine for

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[230] Eric M. Bergerud, *Touched with Fire,* pp. 284 and 291-6; Constance McLaughlin Green, Harry C. Thomson, and Peter C. Roots, *The Ordnance Department: Planning Munitions for War,* pp. 175-8.

[231] War Department, *Basic Field Manual: Jungle Warfare: FM 31-20,* Washington: Government Printing Office, 15 Dec 1941; and *idem, Field Service Regulations: Operations: FM 100-5,* Washington: War Department, 22 May 1941, pp. 235-7.

mountain operations, and developed some equipment (such as the 75 mm pack howitzer) specifically for mountain warfare, it was not until 1941 that jungle warfare seems to have attracted the attention of anyone outside the Philippines and Panama. It may well be that the interest was precipitated by Japan's seizure of the French colony of Indo-China (Vietnam). (As late as 1939, a then-new edition of the top-level doctrine publication did not contain the word *jungle.*[232])

In the summer and fall of 1941 the army undertook its first large-scale exercises since the First World War, the famous Louisiana and Carolina maneuvers. Neither the circumstances nor the scenarios had any particular relevance to war with Japan, showing that even at that late date this was not a major focus for army leadership – no more than war with the U.S. was a focus for IJA leadership.[233]

The maneuvers did have much value in a broader sense, as did other preparations not specifically directed toward Pacific needs. This of course was the case with many of the weapons reviewed earlier and also with radar and guns for air defense.

Radar and electronics

As with the navy, army resources for radar development were slender until 1940. While the two services did communicate with one another about radar development, they were often slow to share critical developments. Each, for instance, independently developed an antenna duplexer (to permit the same antenna to be used both for transmission and reception) and army radar developers learned of the PPI display not from the navy, which had independently developed its version two years before, but from the British. Naturally, there was no shared or coordinated development between the two services, resulting in waste of their meager resources. Like the navy, the army did benefit greatly from access to British technology for microwave transmission. By war's outbreak,

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[232] War Department, *Tentative Field Service Regulations: Operations: FM 100-5,* Washington: War Department, 1939.

[233] Christopher R. Gabel, *The U.S. Army GHQ Maneuvers of 1941.*

microwave transmission. By war's outbreak, army-developed SCR-268 searchlight-control and SCR-270 and SCR-271 early warning radars were starting to come into operation.[234] Use of these radars by the newly-renamed Army Air Forces (AAF) will be discussed below.

As war neared the focus of Signal Corps communications development shifted more and more to radio, and increasingly to highly mobile radios suited to a war of rapid movement. Frequencies moved up to the VHF and then UHF ranges to provide more interference-free channels and limit potential for intercept. Advances in vacuum tubes were exploited to build man-portable sets that could accompany small units in the field to permit far better coordination between units and arms.

There were daunting challenges from users who wanted many channels, sets that could be operated under fire by non-specialists, and clear communications between vehicles on the move. Crystal control and FM provided the answer, but the road to each was strewn with obstacles, political as well as technical. These were overcome well enough to give American ground forces radio communications far in advance of anything the IJA had. The problems of reliable operation in wet tropical environments were resolved only slowly, however, having not been considered adequately in advance.[235]

U.S. Army Air Forces (USAAF)

On the day Hitler attacked Poland, George C. Marshall became the Chief of Staff of the U.S. Army, a post he was to hold for more than six years. More than any of his predecessors, Marshall perceived the transformation the airplane was bringing to war, and he hoped to make good on the promise that air power enthusiasts offered of cheaper, faster victory. With the army ballooning in size and strug-

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[234] Dulany Terrett, *The Signal Corps: The Emergency (To December 1941)*, pp. 46, 124-9, and 185-202.

[235] *Ibid.*, pp. 116-21, 138-65 and 178-84.

gling with the problems of expansion, modernization, and readiness, Marshall sought to streamline administration and command. Because the air forces were growing far faster than the army as a whole and presented issues which were in many ways unique, he was sympathetic with the notion that their administration and command could best be served by some degree of separation from the rest of the army. On 20 June 1941, the Army Air Forces was set up under General H. H. "Hap" Arnold, with broad authority over all air elements. This did not fully resolve the problems and further realignments were found necessary, notably in March 1942, but it was a nevertheless a major step.[236] Even though the new title did not take effect until mid 1941, I will use it throughout this section.

Strategic bombing's unexamined premises

As earlier observed, AAF leaders were skeptical of the relevance of experience in the Sino-Japanese conflict, Spanish Civil War, and early stages of World War II in Europe owing to what they saw as defects in the bomber equipment and doctrine of the major combatants. AAF optimism about the ability of unescorted heavy bombardment aviation to deliver swift knockout blows without crippling losses remained undimmed until they had gained first-hand experience in 1943. That there would be surprises in applying entirely new weapons with entirely novel doctrine was inevitable but those encountered were more painful and costly than they need have been.

Bombing accuracy and guided weapons

One aspect of this was bombing accuracy. AAF bombing tests and exercises continued to be conducted at relatively low altitudes in clear conditions and with no effort to simulate the effects of hostile flak. Operations analysis of actual wartime results was to demonstrate that flak and altitude were the dominant determinants of

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[236] Mark Skinner Watson, *Chief of Staff: Prewar Plans and Preparations,* United States Army in World War II, Washington: Center of Military History, U. S. Army, 1950, pp. 278-98.

bombing error and that each had large effect.[237] Thus the AAF tests led to substantial unwonted optimism.

It was no doubt partly for this reason that air officers seem to have applied no thought to the potential of guided weapons to improve accuracy. While most people think of guided weapons as a late 20th century development, this is inaccurate. Primitive but workable guided weapons had been developed and produced in World War I, although too late to see any action.[238] As discussed earlier, the USN had developed and demonstrated a practical TV guidance system for an "assault drone" by early 1942.

In the meantime, not yet known to the Allies, Germany had been developing two air-launched missiles, an armor-piercing guided bomb and a rocket-boosted missile. Both used the same control hardware, although with different control laws. In both cases the bombardier in the launching aircraft sent radio commands to keep the missile lined up with the target until it hit. With the guided bomb it was necessary for the launch aircraft to slow and climb after release so as not to overrun the bomb. Nothing involved in the design or technology of these weapons went beyond U.S. state of the art. Indeed, there were many points of similarity with the control systems developed by NRL for the USN target and attack drone programs.[239]

In 1940, the NDRC began a project to develop a guided bomb in cooperation with the AAF. This was separate from their project for BUORD, although there does appear to have been mutual aware-

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[237] Thomas I. Edwards, and Murray A. Geisler, *The Causes of Bombing Error: As Determined by Analysis of Eighth Air Force Combat Operations,* Operations Analysis, AC/AS-3, Washington: Army Air Forces, 15 Jul 1947; and Hugh J. Miser, *Estimates of Bombing Accuracy Planning Factors for Visual Bombing,* Assistant for Operations Analysis, Working Paper No. 1, Washington: Headquarters, United States Air Force, 9 Dec 1949.

[238] Bill [William T.] Gunston, *The Illustrated Encyclopedia of the World's Rockets & Missiles,* New York: Crescent Books, 1979, pp. 29, 31-2, and 104-5.

[239] Rowland F. Pocock, *German Guided Missiles of the Second World War,* London: Ian Allan, 1967, pp. 29-42.

ness and perhaps cooperation. Again, it seems that the NDRC people (and presumably their AAF colleagues) were unaware of BUAER's achievements. The initial effort to develop a TV-guided bomb fell afoul of problems which look to have been at least somewhat similar to those BUAER had already solved. Frustrated, the team sought other guidance mechanisms offering greater promise of immediate results. By 1943 they had settled on a system in which the bombardier would guide the bomb to keep it visually lined up with the target – essentially what the Germans had been pursuing since 1938.[240]

This was brought home on 9 September 1943 when nine specially-equipped German planes attacked Italian warships attempting to defect to the Allied side. With nine guided bombs they scored three hits, sinking one battleship and severely damaging another.[241] A number of other Allied ships were hit in short order off the Salerno beachhead, and the threat was abated only when Allied fighters based ashore made it too dangerous for the German bombers to approach the area. (Jamming equipment intended to jam the radio control system was rushed into service, but there is no evidence that it had any effect.[242]) This resolved any doubts within the AAF about whether it wanted a guided bomb.

The NDRC team faced obstacles beyond those confronting their German predecessors, however. For one thing, the AAF insisted that a 1000 lb guided bomb be compatible with existing bomb shackles and fit within the same envelope as a standard service 1000 lb bomb

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[240] Army Air Forces Board, *Controlled Missiles*, Project No. (G)5, Orlando, Florida: AAFSAT [Army Air Forces School of Applied Tactics], 29 Oct 1943; and Joseph C. Boyce, editor, *New Weapons for Air Warfare: Fire-Control Equipment, Proximity Fuzes, and Guided Missiles*, Science in World War II: Office of Scientific Research and Development, Boston: Little, Brown & Co., 1947, pp. 249-58.

[241] Rowland F. Pocock, *German Guided Missiles of the Second World War*, p. 44.

[242] Alfred Price, *The History of U.S. Electronic Warfare: The Years of Innovation—Beginnings to 1946*, Alexandria, Virginia: Association of Old Crows, 1984, pp. 92-4.

so that just as many could be carried in a bomb bay. Moreover, the sort of maneuvers that the Germans used with their relatively light bombers to keep far enough behind the bomb to allow visual alignment in range as well as azimuth were felt by the AAF to be impractical for their heavy bombers. Both problems were eased by a decision to accept an azimuth-only guided bomb, called AZON. This had the same in-trail errors as a free-fall bomb – many hundreds of feet from high altitudes. But the cross-trail errors could be reduced, by a good bombardier, to the order of a few tens of feet.[243] This made the AZON a good choice for hitting narrow linear targets, such as bridges, which ordinarily were very difficult to destroy with bombs. When the bomb was ready for action in mid 1944 the AAF was at first rather reluctant – the NDRC people accused them of being more interested in racking up tonnage dropped than targets killed[244] – but with suitable training and direction specialized units proved capable of doing considerable execution against bridges, at least when opposition was not too heavy. Operations analysis suggested that the AZON was about 15 times as effective as conventional bombs against such targets.[245]

Eventually a two-coordinate guided bomb comparable to the German weapon was developed, the RAZON. This was too late for World War II, although some were used with fair success in Korea.

The point of this long and dismal story is that there was no technical or industrial reason why the AAF could not have had guided bombs at the same time as the Germans, in 1943. For that matter,

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[243] *Trail* is the vector from the ground position of the bomber at time of impact to the impact point. For most purposes, bombing errors are best resolved into components along and across the trail vector.

[244] Joseph C. Boyce, editor, *New Weapons for Air Warfare,* p. 261.

[245] Army Air Forces Board, *Test of VB-2 (2,000 lb. Azon Bomb),* AAF Board Project No. 4362B471.6, Orlando, Florida: Army Air Forces Center, 6 Sep 1945; Joseph C. Boyce, editor, *New Weapons for Air Warfare,* pp. 259-63; and Operations Analysis Section, India-Burma Theater, *Azon (VB-1) in India-Burma Theater,* 05-8457, AF, Headquarters, Army Air Forces, India-Burma Theater, 21 Mar 1945.

there seems no reason why it could not have had a TV-guided weapon, a sort of proto-Walleye (assuming the navy could somehow have been persuaded to yield its secrets). This was not, strictly speaking, a failure in doctrinal vision. Rather, the AAF had not done what it might have to determine how well its selected means of high-altitude free-fall bombing could meet its doctrine of precise and selective target destruction. Precision weapons could not, with the technology available, have entirely closed the gap between vision and reality, but they would have helped significantly.

Finding the right targets

Another yawning gap was that between the attractive idea of identifying and destroying the putative small number of critical nodes in the industrial web and the actual process of finding them. Officers at the Air Corps Tactical School did make an effort at this, as best they could, but their resources and knowledge were severely inadequate. Experience was to show starkly how resilient and redundant the web of a modern industrial society truly was.[246]

To be fair, it is not at all clear that the knowledge existed before the experience of war to evaluate the idea very well. They couldn't bomb a few supposedly critical nodes to find out what would happen, after all. I suspect that few scientists or engineers held serious doubts about the idea of critical nodes beforehand, although some economists may have. And it is difficult to see how the analysis tools then available could have revealed the truth. So this must be chalked up as one of those unknowables that are always a threat to plausible but untested and untestable theories.

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[246] For an overall review and assessment see Robert A. Pape, *Bombing to Win: Air Power and Coercion in War,* Ithaca: Cornell University Press, 1996. Two revealing studies of specific cases are Josef W. Konvitz, "Bombs, Cities, and Submarines: Allied Bombing of the French Ports, 1942-1943," *International History Review,* Vol. 14, No. 1 (Feb 92), pp. 23-44; and *idem,* "Why Cities Don't Die: The Surprising Lessons of Precision Bombing in World War II and Vietnam," *American Heritage of Invention and Technology,* Vol. 5, No. 3 (Winter 1990), pp. 58-63.

Bomber survivability

A more foreseeable defect was that of bomber survivability. As noted before, this needs to be placed in perspective. If strategic bombing could knock an enemy out of the war with a small number of sorties per bomber, then relatively high attrition per sortie might seem quite acceptable. For instance, if it could be done with 5 sorties per bomber and each involved loss of 13% of the planes involved, then 50% of the bombers would still be left at the moment of victory.[247] It would be a high price for the bomber crews, but one they probably were willing to contemplate in return for the opportunity to so serve their nation and service. These were ardent, dedicated men very used to taking high risks – flying military aircraft was inherently quite risky in those days, even in peace, and they had seen many comrades fall to accidents. I think it very unlikely that they imagined their bombers would literally get a free ride to triumph.

Even making full allowance for this, it seems that they were unwontedly sanguine. The point has often been made that they were ignorant of radar, and some have suggested that they might have taken a very different view had they known of it. But even when the army's ground forces lacked funds to exercise above the company level, resources were found for relatively large scale air exercises. Bomber advocates trumpeted these as showing that bombers could perform their missions with little risk, but an objective examination of the results casts great doubt on this view, even leaving radar entirely out of the picture.[248] Nor did the views of the AAF leadership show significant alteration after they learned of radar in 1937.

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[247] The losses must be compounded, so that the formula is $R_n = 1 - (1 - r)^n$, where R_n is the rate of loss in n sorties and r is the rate of loss per sortie. Thus in 10 sorties with a loss rate per sortie of 10% = 0.1, the total loss rate will be $1 - (1 - 0.1)^{10} = 1 - 0.9^{10} = 1 - .349 = .651 = 65.1\%$.

[248] Hugh G. Severs, "The Controversy Behind the Air Corps Tactical School's Strategic Bombardment Theory: An Analysis of the Bombardment Versus Pursuit Aviation Data Between 1930-1939," Graduate research paper, Air Command and Staff College, Air University, Maxwell Air Force Base, Alabama, 1997.

Bombardment advocates argued that their raiders would have little vulnerability to AA guns because of their high flight altitudes. This was a valid argument so long as the defenders possessed no AA guns better than the U.S. Army's 3 inch weapon. But Germany and even Japan were developing more powerful weapons and better fire control. In Europe, the AAF was to lose ten thousand bombers, half of them to German flak. Moreover, as the bombers sought higher altitudes to reduce exposure to AA, the percentage of their bombs that fell on target declined sharply, blunting their effectiveness. Had Germany or Japan developed the proximity fuze, the situation would have become dire indeed.[249]

In World War I and through most of the 1920s, it had been accepted that daylight bombing raids needed fighter escort. This came to seem less feasible as bomber ranges grew sharply in the 1930s. Bombardment-minded officers believed that modern bombers could dispense with fighter escort if they flew fast, high, and in close formation where they could support one another with defensive fire. The idea of long-range escort fighters was examined cursorily and summarily pronounced infeasible without having consulted those well qualified to make an assessment. Experiments in external tankage to extend fighter range were abandoned out of safety concerns in event of a wheels-up landing and provisions for such tanks forbidden.

Nor was there much effort in strengthening defensive firepower. Although the inadequacy of rifle-caliber machine guns for aerial defense had been well recognized in World War I, many bombers entered World War II with .30 caliber guns. No effort was made to provide defense astern, although it was obvious that this was the region of greatest vulnerability. Little effort was put into power turrets. All of this changed in 1940 when the lessons of the European

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[249] Operations Analysis, AC/AS-3, *Estimate of Effect on Eighth Air Force Operations if German Antiaircraft Defenses Had Used Proximity-Fuzed (VT) Ammunition,* Report No. 1, C7-6728, AF, Washington: Headquarters, Army Air Forces, 15 Feb 1947.

war started to be studied. But it was too late to provide much better defensive armament in time for the first test of war.[250]

Unconsidered limits

The deficiencies of AAF heavy bombers in vulnerability to AA and fighters mattered less in early encounters with Japan than they did in Europe, where German flak and fighter defenses were a great deal stronger than in the South and Southwest Pacific. Nor did the difficulty in identifying critical strategic targets matter very much: there simply were no strategic targets, as the AAF defined them, in reach of AAF "long-range" bombers. It was only the 1944 capture of bases in the Mariana Islands that brought Japan's industrial and population centers within practical reach of the very longest-ranged of bombers, the new B-29. And only the 1945 capture of Iwo Jima permitted the B-29s to operate with reasonable freedom and security. These two very costly combined-arms amphibious campaigns were an unavoidable part of the price of strategic airpower in the Pacific.

Fighters

Fortunately, the AAF did not focus quite so single-mindedly on strategic bombardment as some of its pronouncements suggested. There were AAF officers who, at the risk of their careers, disputed the sole concentration on strategic bombing. Senior officers of the ground forces applied what pressure they could in favor of support for ground operations. Congress made demands of its own, particularly after the outbreak of war in Europe. Public opinion demanded visibly "defensive" forms of air power. And ultimately, even some of the most strident of bomber advocates moderated their stances as they gained in rank and responsibility, whether out of sincere change of heart or compliance with political necessity.

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[250] Irving B[rinton] Holley, Jr., "The Development of Defensive Armament for U.S. Army Bombers, 1918-1941: A Study in Doctrinal Failure and Production Success," in *The Conduct of the Air War in the Second World War.*

Thus other classes of aviation forces were neglected before the war, but not so thoroughly as they might have been. The air arm did continue to develop some fighters, attack aircraft, and observation planes for supporting ground forces, and added a new class of medium bombers between the four-engined B-17 and the light attack aircraft.

All this was both helped and hindered – but more helped – by the arrival of French and British delegations looking for aircraft to meet the German threat, starting in 1938. At least one aircraft that was to prove extremely valuable, the North American P-51 Mustang, was developed in response to British requirements and initially received a distinctly cool reception from the AAF. European orders and money prompted and permitted the expansion of the aircraft industry in the period before expansion of the AAF. The tradeoff, of course, was that the Europeans were competing with the AAF (and USN) for manufacturing capacity, but in the meantime they helped to expand it.

Fighters presented a special problem. They would be needed before anything else, and the AAF did not recognize this until war was nearly upon them. Unfortunately, it is impossible to concoct good fighters quickly.

The greatest problem was engines. In-line liquid-cooled engines lent themselves best to fighters, but suitable ones were not to be had in the U.S. This was a direct result of Air Corps policy, or lack of it, between the wars. The U.S. Curtiss firm had manufactured the best liquid-cooled engines in the world in the mid 1920s. But while liquid-cooled engines were preferred for fighters, they were not entirely suited to the needs of the USN or of heavy aircraft – such as heavy bombers. The USN sponsored development of air-cooled radial engines. Commercial operators liked the radials too, particularly after a Wright J-5 Whirlwind powered Charles A. Lindbergh's 1927 33-hour flight from New York to Paris. The position of the ra-

dial was further bolstered when the NACA developed a cowling that greatly reduced cooling drag, while actually improving cooling.[251]

The Air Corps was the last market for liquid-cooled engines. But radials served very well for bombers. It was only fighters and other small, fast planes that really benefited from the lower drag potential of liquid cooling. But this was a potential in some doubt until development of high-temperature pressurized cooling systems permitted radiator sizes to be much compressed. In an effort to cut radiator sizes as much as (really more than) was possible, the army insisted on unrealistic specifications for coolants and temperatures and penalized Curtiss for not meeting them. Curtiss and Wright merged in 1929. Lacking incentives to pursue liquid-cooled development, C-W never made an engine of this type after the early 1930s.[252] Packard, the other major liquid-cooled manufacturer, became absorbed in an ill-fated effort to develop a Diesel aero engine and eventually exited the aero business until it undertook to manufacture the Rolls-Royce Merlin during World War II.

That the U.S. had any liquid-cooled engines for fighters at all came about through a seemingly-improbable set of accidents – certainly not by sound Air Corps policy. The engine was the Allison V-1710[253] and it (and its maker) survived a series of vicissitudes to become the first engine to make it through the AAF's severe 150-hour test (or any equivalent qualification test elsewhere) at a rating of 1000 HP, a milestone passed early in 1937. It was fundamentally a very good engine, still prized today by racers of piston-engined planes and

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[251] C[harles] Fayette Taylor, *Aircraft Propulsion: A Review of the Evolution of Aircraft Piston Engines*, Smithsonian Annals of Flight, Vol. 1, No. 4 (End of volume), Washington: Smithsonian Institution Press, 1971, pp. 35-56.

[252] Hugo T. Byttebier, *The Curtiss D-12 Aero Engine*, Washington: Smithsonian Institution Press, 1972, pp. 74-81.

[253] American military engines were designated by a one- or two-letter code denoting layout (R for radial, V for in-line vee, etc.) followed by a number denoting the swept volume in cubic inches, to the nearest multiple of five. Thus, for instance, the Packard-built version of the Rolls-Royce Merlin became the V-1650 in U.S. service.

boats. But its development was not pressed vigorously and by 1941 it was half a step behind the British and German competition, particularly in regard to altitude performance. Again, this was in large measure due to the AAF, in significant part because developments more useful for bombers took priority. During World War II the AAF replaced the Allison in its best fighter, the P-51, with a license-built Merlin, thus getting better performance than the V-1710 could have supplied at its then-current state of development and making it the best all-around fighter of the war.[254]

A single young Air Corps officer – Lieutenant Benjamin S. Kelsey – had responsibility for all army fighter development from 1934.[255] He was a very capable and well-educated young man, but he was left largely on his own to swim with the sharks – politically-connected aircraft manufacturers desperate for Air Corps contracts in the Depression of the 1930s. He was kept busy.

A fighter design competition in early 1934 was won by a streamlined monoplane with a retractable landing gear and closed cockpit – a first, ahead of its time. But aeronautical progress was so rapid that it was obsolete before it left the drawing board and was never built. Another competition, announced 18 months later, required prototypes for a flyoff. It turned into a free-for-all from which eventually emerged the Seversky P-35 and the Curtiss P-36. Both were metal streamlined low-wing monoplanes with retracting gear and closed cockpits, generally similar in layout and appearance to World War II fighters and a huge step from any previous AAF plane of this type. Both were powered by radial engines – there being no other choice in the U.S. at the time. They reached service in mid 1938. The P-36, sold to France, saw action in 1940 against German Messerschmitt fighters. It was overmatched but managed nevertheless to give a reasonably good account of itself due to being rugged and nimble. By

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[254] Daniel D. Whitney, *Vee's For Victory! The Story of the Allison V-1710 Aircraft Engine, 1929-1948*, Atglen, Pennsylvania: Schiffer Military History, 1998, pp. 9-172 and 316-38.

[255] Benjamin S. Kelsey, *The Dragon's Teeth? The Creation of United States Air Power for World War II*, Washington: Smithsonian Institution Press, 1982.

Pearl Harbor both were rated as obsolete by the AAF but saw some action; the P-35 was next to useless but P-36s managed a few kills.[256]

Both aircraft saw further development for the AAF. The tenth P-36 off the line was fitted with an Allison V-1710 liquid-cooled engine in a revised nose section, becoming the prototype of the P-40. It first flew late in 1938 and P-40s of various models were the mainstay of the AAF in the Pacific for the first year of war. When the British tried it in Europe they found the P-40 quite unsuitable due to lack of speed and altitude capability as well as poor rate of climb. (On the other hand it served well in North Africa, where its ability to keep going in difficult environments – a characteristic of U.S. fighters designed to work well whether in Alaska, the Philippines, or the deserts of the American Southwest – gave it a margin over planes designed specifically for European service.) But it was a bit faster than the Japanese A6M or Ki-43 fighters, and much more rugged and well armed, so it was able to hold its own against them when employed with appropriate tactics.[257]

The P-35 became the progenitor, four generations removed, of the Republic P-47, a large and very powerful fighter that became quite important in Europe from late 1943 on and eventually played a valuable role in the Pacific as well.[258] In the meantime, however, the AAF had launched a design competition for two versions of a high-altitude interceptor. The terms of the competition, issued early in 1937, called for selection of one single-engined and one twin-engined type, both to be powered by Allison liquid-cooled V-1710s,

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[256] Ray Wagner, *American Combat Planes*, pp. 236-48.

[257] Eric M. Bergerud, *Fire in the Sky: The Air War in the South Pacific*, Boulder: Westview Press, 2000, pp. 240-7; Francis H. Dean, *America's Hundred-Thousand: U.S. Production Fighters of World War Two*, Atglen, Pennsylvania: Schiffer Military History, 1997, pp. 227-76; and Ray Wagner, *American Combat Planes*, pp. 252-7.

[258] Warren M. Bodie, *Republic's P-47 Thunderbolt: From Seversky to Victory*. Hiawassee, Georgia: Widewing Publications, 1994; and Ray Wagner, *American Combat Planes*, pp. 273-80. The generations were the P-35, XP-41, P-43, and (unbuilt) P-44.

with one aircraft planned to go into production following a flyoff. The competition was won by quite novel designs from two firms that had no history of fighter production. Lockheed's twin-engined P-38 – with a very high aspect-ratio wing, two fuselages or "booms" carrying engines and tail surfaces flanking a small nacelle for pilot and guns, and tricycle gear – first flew two years after the competition had been announced and created a sensation with its high speed and sleek looks.[259]

The P-38's development into a fighting plane was a protracted and tortuous process, however, bedeviled by Lockheed's inexperience (it had never designed a fighter before, only transports), lack of capital, and diversion by more profitable European orders, as well as the travails of developing the turbosuperchargers that it depended upon for altitude performance. In addition, it was the first plane with performance high enough to encounter serious problems with what was then called "compressibility" – brushing against its critical Mach number (which was somewhat lower than for some other high-speed fighters, due to its configuration) in dives, causing alarming and dangerous control problems. It was all sorted out in the end and the P-38, never used as an interceptor and not terribly successful in Europe, became the dominant AAF fighter in the Pacific and a great scourge to the Japanese. But that did not come until 1943.[260]

Lt. Kelsey seems to have felt some attraction to very unusual designs, because the Bell P-39, too, was a great departure from the norm. The company's only previous experience had been designing and

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[259] Warren M. Bodie, *The Lockheed P-38 Lightning*, Hiawassee, Georgia: Widewing Publications, 1991, pp. x-xii, 14-24, and 32-42; Benjamin S. Kelsey, *The Dragon's Teeth?* 113-7.

[260] Eric M. Bergerud, *Fire in the Sky*, pp. 262-8; Warren M. Bodie, *The Lockheed P-38 Lightning*, pp. 43-77 and 104-16; Francis H. Dean, *America's Hundred-Thousand*, pp. 137-87; R[ichard] L. Foss and Roy Blay, "From Propellers to Jets in Fighter Aircraft Design," *Lockheed Horizons*, No. 23 (Apr 1987), pp. 3-17; David W. Ostrowski, "Early P-38 Problems," *Skyways*, (Oct 1996), pp. 54-64; and Daniel D. Whitney, "The Allison Time Bomb," *Torque Meter*, Vol. 1, No. 2 (Spring 2002), pp. 14-33.

producing a small run of test articles of a gargantuan twin-engined "fighter" with a four-man crew and two 37 mm cannon – one of the most bizarre airplanes of its time, built for an air force that constantly complained of want of money. The P-39 was more conventional in general layout but featured an engine mounted behind the cockpit and driving the prop through a long shaft, a 37 mm cannon firing through the prop hub, and tricycle landing gear. It was a very compact, sleek, and lightweight aircraft and the prototype, first flying in April 1939, delivered sprightly performance, if somewhat short of expectation due to some aerodynamic problems.[261]

Unfortunately, no other P-39 ever performed as well. The prototype had a turbosupercharger to give good performance at high altitude but the plane was really too small, as it turned out, for a good installation and the turbo was not installed in any subsequent model. Because the mechanical supercharging options for the V-1710 were limited, this meant that the performance would be mediocre above 15,000 feet or so. When fitted with adequate armament, armor, and equipment for modern combat (mostly not originally envisioned) the plane's weight increased sharply – a weight increase it was too small to accommodate well. (The same problem the Japanese faced, or rather failed to face.) The 37 mm gun fired too slowly and had too low a muzzle velocity to be very suitable for fighter use. (A new, and heavier, version came along in 1943 with much improved muzzle velocity, but no better firing rate.)[262] Finally, the layout left little room for fuel. On the whole the P-39 was less well suited to Pacific

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[261] Birch Matthews, "Airacobra Mystery," American Aviation Historical Society, *AAHS Journal*, (Winter 2001), pp. 290-9; and *idem, Cobra! Bell Aircraft Corporation, 1934-1946.* Atglen, Pennsylvania: Schiffer Military History, 1996, pp. 15-88.

[262] Ordnance Department, *Catalogue of Standard Ordnance Items*, Vol. 2, pp. 379-80.

Theater needs than the P-40, but was nevertheless pressed into service in 1942 and did useful work.[263]

The story of AAF fighters in the early months of the Pacific War is really quite remarkable. The airplane that was intended to fill the role of general purpose tactical fighter, the P-40, proved marginal at best. It could hold its own in combat with Japanese fighters of the early war period. But its poor climb and altitude performance made it ineffective as an interceptor against high-altitude bombing attacks. And its lack of significant performance margin over Japanese fighters limited it to largely defensive roles. Moreover, had the Japanese succeeded in introducing more advanced types as they had planned, the P-40 would quickly have been outclassed. The P-40 remained in combat service to the end of the war, but was increasingly relegated to secondary roles after 1942.

The P-38 was designed with no particular thought of either the Pacific or general fighter duties – it was a classic point-design interceptor. It never fit the mental "fighter model" held by most people. Yet it proved remarkably good at the role. It was eclipsed in Europe by more conventional fighters, the P-47 and P-51, but not by much of a margin; had they not come along it would have served very nearly as well. Over the vast, lonely stretches of the Pacific, it proved a very hard airplane to beat. It was the sole aircraft of its design generation, and the only one powered by the V-1710 engine, to successfully fill the need for a high-altitude long-range fighter. It was almost exactly contemporary with the A6M Zero, but proved much its superior in Pacific combat and remained effective far longer.[264] (It took much longer to get into action, however.) But no one had really planned it that way: it was a product of good fortune, exceptionally inspired aircraft design, and painstaking development.

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[263] Eric M. Bergerud, *Fire in the Sky,* pp. 247-50; Francis H. Dean, *America's Hundred-Thousand,* pp. 188-226; and Birch Matthews, *Cobra!* pp. 89-125 and 149-77.

[264] Army Air Forces Board, *Test of Comparative Performance Between the Japanese "Zeke" 52 and the P-38, P-47 and P-51 Type Aircraft,* Orlando, Florida: Army Air Forces Proving Ground Command, 3 Apr 1945.

Loose ends and open questions

The broad comparative approach of this paper has produced insights that would not otherwise have been so apparent. Before summarizing them in the next section, however, it is well to recognize that this is a preliminary effort, limited in scope, which has left some significant open questions.[265]

Where does superiority in operations come from?

The point has been made more than once that the key superiority of the U.S. forces in the early phase of the war, before the superior economic resources of the U.S. had a chance to take effect, was in operational movement and logistics. American commanders simply were better at forcing action at places and times where their forces could hold the advantage in terms of firepower and support. Although at a tactical level the campaign, particularly in the South and Southwest Pacific, often looked like the most brutal sort of siege warfare, at the operational level it was definitely a campaign of maneuver – and the U.S. and its allies consistently outmaneuvered the Japanese.

It is very important to know, then, how this came about. Why were the Americans so good at operational-level maneuver and logistics? Why were the Japanese so bad? The answer often given is "culture." This is surely correct in a sense, but it begs the question of what shaped the culture. Was this simply a cultural trait that was inherent in the broader cultural context of the two nations? After all, even today economists identify examples of notable inefficiency in the in-

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[265] This is not intended in any way as critical of the support provided by the sponsor, which has been very generous by usual standards. The problem has been not that the resources have been meager but that the scope inherent in such an effort is very broad.

ternal logistics of key Japanese economic sectors.[266] Yet everybody by now knows that many Japanese companies in international trade quickly achieved exemplary levels of logistical excellence after the war.[267] Nor has the logistical performance of American firms consistently outpaced that of their Japanese counterparts by any means. Thus we can scarcely conclude that logistical ineptitude is a fundamental Japanese cultural trait or that logistical efficiency is inherent to American culture, and similarly for operational maneuver.

It is almost surely of some significance that both of the Japanese services did poorly in logistics and all of the American ones did relatively well. There do seem to be some fairly broad influences at work, extending beyond particular services. One obvious and reasonably plausible hypothesis would be that the Japanese military over-reliance on martial spirit was corrosive of the cool rationality required for operational excellence. Another might be that the problem was related to the intensity of political struggle between and within the Japanese services. It may also have been affected by the relative material modernity in America and habits of mind that it breeds. Or the greater civilian influence in the U.S. services may have given them an important edge.

All of these hypotheses have been advanced at one time or another in this connection. None, however, seem to have been examined in a comparative context. Such an examination might lead to important clues in understanding a key phenomenon of military advantage, not only in the past but in the future.

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[266] Richard Katz, *Japan: The System that Soured – The Rise and Fall of the Japanese Economic Miracle,* Armonk: M. E. Sharpe, 1998, pp. 29-46.

[267] See, e.g., James P. Womack, Daniel T. Jones and Daniel Roos, *The Machine that Changed the World: The Story of Lean Production,* New York: HarperCollins, 1991, pp. 138-68.

What makes for good PME?

Somewhat related is the issue of professional military education (PME). In both Japan and the U.S., army and navy both had well-established war colleges, and there were several other important PME institutions. In both nations, the great majority of those who held flag rank in World War II were war college graduates, and war college graduates were far more likely to be promoted to high grades than those who lacked this background.

Failings of the Japanese war colleges have been widely remarked. Following World War II the U.S. Naval War College was given public credit by some of its very illustrious graduates as a cradle of victory, with the wargaming program at the NWC receiving particular praise. While praise of the U.S. Army War College seems to have been less public, it along with the Command and General Staff College have been widely sited as a source of army excellence. All this tends to leave an impression that superiority in PME was one of the obvious keys to American strength.

But the American institutions have not by any means escaped from criticism. The NWC of the 1930s is portrayed as a bastion of the "gun club", hewing to a conservative doctrine in which aircraft and submarines played second fiddle and logistics and amphibious operations were afterthoughts. The U.S. Army PME institutions are accused of sterile thinking. Nor was wargaming by any means exclusive to America.

Thus there is a real question of whether American PME truly was superior, and if so what this superiority consisted in. This too is clearly a question with great contemporary significance, offering clues not only to how to strengthen our own PME but also what to look for to indicate how successful the PME of possible opponents might be.

Questions of scope

If a broad scope has been good, might not an even broader scope be better? In particular, if a systemic comparative examination of the case of the U.S. and Japan has been productive, would it not be valuable to extend the effort to consider all of the major combatants in World War II in a common frame – Britain and Germany and perhaps France and the USSR as well? In principle it clearly would be.

Some thought must be given to questions of scope vs. depth vs. resources. A look at the bibliography of this report is useful. It contains about 850 entries covering all of the major documents surveyed and found to be at least potentially relevant. (Several hundred more were examined in various degree but set aside as not relevant enough to be worthwhile.) Together they include something in excess of 20 million words of text. Selecting, assembling, assessing, reading, processing, and exploiting such a research collection takes time. Even though I began the project with substantial portions of the material already in hand and much of that already read and processed (and even though some of it is simply reference material not needing to be read), there is a good deal of material here that I have yet to do justice to.

Some of these works would be fully applicable to the cases of other nations in this period. Nevertheless, it is reasonable to suppose that adding Britain and German to the comparative mix would at least double the size of the bibliography, and France and the USSR would bring significant further expansion. This would imply a very considerable investment which would have to be set against the anticipated gains.

Given this, it might be reasonable, at least initially, to expand the scope on less than a fully systemic basis, concentrating on specific areas of comparison. In particular it might be quite productive to examine the issues of the sources of operational excellence and of the influence of PME in the context of more than just two nations. There is an obvious risk in, for example, examining the issues of operational excellence in the cases of Britain and Germany without

fully considering all of the elements of the system – one might more readily misidentify the causes of observed differences. But as it is impossible to study everything at once in any event, it makes some sense to concentrate first on those issues of most immediate importance.

Conclusion

War happens, whether "rational" or not

The first lesson of the Pacific War is that it happened at all. Many American officials had discounted the idea that Japan might attack the U.S., with its vastly greater economic-military potential. What was nearly impossible to understand from the outside was the strength of the internal political forces driving Japan to war. Ultimately, the nation's leadership chose war, despite misgivings, because they saw a chance of victory, even if slight, as better than the political upheaval they felt certain would overwhelm them otherwise. Thus the U.S. faced an "irrational" attack that it was not immediately prepared to counter. Clearly, it is irrational on our part to count too strongly on what we regard as "rational" behavior on the part of nations whose internal dynamics we do not and cannot fully understand.

Even Japanese officers who had a reasonably clear understanding of the U.S. and its forces were shocked at the speed with which their adversary went over to the strategic offensive after the first few months of war and how relentlessly and effectively it was pursued. They could calculate well enough that the great rearmament program started by the U.S. in mid 1940 would begin to bring overwhelming forces on line by the end of 1943. What they did not count on was that well before then the U.S., without any real superiority in matériel, would so severely have eroded Japan's forces and strategic position as it in fact did. It was this early part of the war, up to the fall of 1943, that clearly reflects the strengths and weaknesses of Japanese and American approaches to transformation.

Transformation = concept + doctrine

Japanese transformation efforts had focused, quite consciously, on tactical execution. Japan built forces whose tactical doctrine was often very sound and whose training and motivation were almost always superb. They were equipped with matériel precisely tailored to their doctrine, usually quite effectively so. When fighting on even terms, Japanese forces early in the war were usually very formidable.

Much American transformation also focused on the tactical level. Even the Army Air Forces, though aiming for strategic effect in their heavy bomber forces, concentrated on the tactics of penetration and bombing. While notable achievements in tactical transformation were reached in some areas, on the whole U.S. forces did not reach a level of tactical excellence equal to that of the early Japanese forces until well into the war. Where Americans did gain tactical dominance relatively early, it was often against Japanese forces that had been degraded in quality or quantity of manpower or matériel.

Operations can dominate

If the Americans began with roughly equal force levels and no edge in tactical effectiveness, how did they manage to damage the Japanese so severely by the end of 1943, before they had received major additions to their strength? To a great extent, the answer comes down to operational factors: the U.S. pretty consistently managed to pit strength against weakness. The key elements of this were superiority in planning, intelligence, logistical infrastructure, and operational and strategic mobility.

Silver bullets

But what of the role of "super-weapons" or "silver bullets"?

Radar was certainly one of the most dramatic and important innovations of the war. While Japan fielded radars almost as soon as the U.S. had, Japanese radar always lagged in quantity and quality. This

was not primarily the result of any general Japanese inferiority in electronics technology: the U.S. simply moved ahead on radar much earlier. Thus radar is a very clear transformational success for the U.S., albeit with significant benefit from the alliance with Britain after 1940.

Certainly radar made a difference. It was one of the factors, for instance, that allowed U.S. forces to cling to their precarious and critical toehold on the crucial airstrip on Guadalcanal – SCR-268 and SCR-270 radars providing warning of bombing attacks, radars on navy ships helping to counterbalance the Japanese excellence in night operations. But it was one factor, along with others also essential – the skillful and tenacious marine ground defense of the airfield against attacks by numerically superior forces, for instance, or the tactical adaptations of navy surface forces. We can say that it was *a* critical factor, but not *the* critical factor. It was a horseshoe nail whose absence might have cost the battle or kingdom, but only one among several.

Much the same could be said in varying degrees and ways for a good many other specific innovations, on both sides. Important – but as part of an overall matrix, not pivotal in isolation. Some weapons were indeed "super", but none was "decisive". Thus to understand transformation's impact we must look not to individual transformative innovations but to transformative complexes which imbed and coordinate critical innovations with, in many cases, relatively untransformed "legacy" elements.

Conceptual-doctrinal complexes

The major conceptual and doctrinal complexes within which the various services located their transformational efforts included:

- For the USN the dominant complex was decisive fleet action, defeating the Japanese fleet at sea in order to clear the way for the final blockade and defeat of Japan. Some would say that it was battleship action, but this is incorrect – however ardently some officers may have supported the battleship (or some

other means) the institutional focus always was on the end. Because the aim was domination of the Western Pacific, thousands of miles from U.S. bases, the complex necessarily included elements of support for sustained long-distance operations.

- The IJN's vision was almost exactly complementary – it sought a complex able to defeat the U.S. fleet in a great sea battle and thus assure Japanese dominance and freedom of action in the Western Pacific. It thought not in terms of a battle force in isolation but of an integrated multi-component force deploying in depth in space and time from the enemy's bases to the final meeting of battle lines (after the opposing forces had been gravely weakened) and the ensuing pursuit and mop-up.
- During most of the interwar period the U.S. Army thought in terms of an infantry-artillery complex with the necessary supporting arms and services, able to take the field at home or abroad against modern armies generally and defeat them in open warfare, in a war dominated by offensive movement. Toward the end of the period this shifted more toward an integrated combined-arms vision. Although there was concern about needs for operations in North America, the army kept in mind the possibility that it might again have to move a huge force overseas. Moreover, even in thinking about operations in North America it was very aware of the problems of logistics and force movement across vast regions with limited transportation nets.
- The IJA's vision was in many ways parallel to that of the U.S. Army, although it placed less emphasis on artillery and somewhat more emphasis on armor. (Not very much emphasis on armor, but more than the U.S.) Where the U.S. Army's focus was quite unspecific regarding prospective enemy, the IJA's was fairly strongly on the U.S.S.R., whose material superiority was to be offset with infantry superior in moral force and tactical execution. The IJA's thinking did not extend to operations over great spans of distance or time.

- Semi-independent of but tied closely to the USN, the USMC conceived a quite novel complex, one innovative in itself, involving seizure and defense of island bases to permit the USN to make its westward advance. For what appear to be largely cultural rather than rational reasons, the navy did not show deep commitment to this critical element of support for their vision, but did give it at least modest support, as did the army as well.

- The USAAC/USAAF was another semi-independent service, but conceived of its critical mission as all but wholly independent: delivering a quick knock-out blow with heavy bombardment of an enemy's key industrial links at war's outset, rendering other forms of military force altogether secondary. Most of its effort was devoted to building a force of heavy bombers to implement this. Secondary complexes were devoted to supporting the army in the field and providing air and sea defense.

Daring is not enough

The prize for the most innovative and sweeping of these concepts must clearly go to the USAAF and its idea of defeating the enemy at virtually a single stroke delivered to his critical industrial infrastructure. It was (and remains) a daring and appealing vision, and it was eagerly embraced by American political leaders and even by some key non-aviation officers in the army. But the U.S. could not even come close to implementing it in the Pacific. At war's outbreak large fraction of USAAF heavy B-17 bomber forces were in the Philippines – the U.S. base closest to Japan and putatively a suitable launch point for bomber raids on Japanese cities. They never made an attack on Japan and proved able to do little to slow the Japanese advance. After loss of the Philippines it took nearly three years and great and costly efforts by other arms to secure bases from which the more advanced B-29 could raid Japan. By this time much of Japan's industrial web was slack owing to lack of critical materials and labor inputs. The B-29 attacks certainly played an important role in Ja-

pan's defeat, but did not swiftly or decisively drive the nation to surrender.

The heavy bomber forces themselves proved very valuable for many other purposes and may well have contributed as much or more to Japan's defeat by their other operations as they did by strategic bombardment per se. Tactical and interdiction raids by heavy bombers (chiefly B-24s rather than B-17s, for a variety of reasons) against targets out of reach of other forces did a great deal to enable U.S. ground and sea advances. Heavy bombers also provided invaluable surveillance and reconnaissance over the vast stretches of the Pacific. And even the super-heavy strategic B-29s devoted substantial effort to laying sea mines – a mission not earlier contemplated by AAF doctrine and smacking of naval blockade, but having genuine strategic effect on Japan's remaining industry by choking off the last vestiges of supplies of critical materials from overseas (not to say food supplies to support the population). So the heavy bombardment *force* proved very important, but largely not in the context of the transformative strategic bombardment *vision* that it had been created to implement.

But while heavy bombardment was a very valuable contribution to victory in the Pacific, it might have been made more valuable had it been possible to guide its development with a clearer and more relevant vision of transformation. For instance, had the AAF made a realistic assessment of the limitations of free-fall bombing it might have been motivated to promote earlier development of guided air-dropped weapons – and the history strongly suggests that such efforts could have borne quite useful fruit. And of course an earlier recognition of the needs for long-range escort would have brought as much benefit in the Pacific as in Europe.

So we reach an antinomy, illustrated many times in the war: innovations have meaning only in multi-component complexes unified by doctrine and implemented through operations and tactics – yet often the complexes in which innovations made some of their greatest contributions were very different from those which had first called them forth. The more pure and intense the vision the more persuasive and effective it tended to be in generating and guiding innova-

tion in peace – and the greater the risk that it might not prove relevant or implementable as conceived in war. And the less comprehensively relevant the guiding vision, the more likely that the innovations associated with it would prove less than fully capable of serving warfighting needs.

There were some important exceptions. The innovations conceived to implement the USMC's concept of amphibious assault served precisely the purposes for which originally intended, and very effectively. Of all the service transformative visions listed above, amphibious assault was far the most successful as a realistic and relevant blueprint (although it is the case that the amphibious forces proved very valuable in ways not originally envisioned, and that many of the innovations it involved required more than one try before they worked well). Why was the USMC so relatively successful in precisely matching vision to reality and thus fostering focused and relevant innovation?

The marines set for themselves a very precisely and clearly delineated task: take islands to serve as bases. It was a task embedded within and clearly critical to a strategy of Transpacific offensive that had been fairly widely agreed already and turned out to be fundamentally sound. That this turned out so was not simply serendipitous, for the Transpacific offensive strategy had been studied with reasonable comprehensiveness and thoroughness by the navy in coordination with the marines and army. The marines in turn thought out their chosen part of this with a fair degree of thoroughness and a certain amount of relevant experimentation and test. In short, they proceeded in what might well be called a scientific manner, formulating a vision untainted by hallucination.

This is not to say that USMC/USN amphibious assault was a scenario-based concept. It represented a capability that was relevant to taking any island, or any reasonably isolated beachhead. It was conceived of in the context of the Central Pacific but was not implemented in a manner specific to that theater. While not entirely what would today be regarded as a capabilities-based concept, it went some distance in that direction.

In principle it might seem that strategic heavy bombardment of an enemy's industrial web represented a more fully capabilities-based concept of universal applicability. But closer examination shows this to be an illusion. It was not specific to a particular scenario, but it was not truly relevant to any scenario, at least not with the means of that day. Strategic bombardment proponents were to contend (as some still do) that they could have knocked Germany and Japan out of the war by themselves if only they had been given more resources and time. That is as may be, but the resources and time they were in fact given vastly outstripped what their original concept had called for.

Getting the technology right

Historians caution us against simple technological determinism – against treating technology as an independent and unbound causative agent – and are surely right to do so. Nor is it possible, as we have seen, to identify particular technological products that can truly be said to have played a decisive part. At the same time, we must recognize that technology plays a pivotal role in transformation, particularly in regard to determining the boundaries of the possible.

Three technological complexes were particularly vigorous and widely recognized as such in the decades preceding World War II:

- **Internal combustion engines (ICEs).** Spark-ignition gasoline engines had made possible the aeronautical and automotive revolutions, with profound effects on society and the economy – and war. Compression-ignition Diesel engines were having great impact in marine and industrial applications, and increasingly in heavy road, rail, and off-road traction. The upper limits of output per unit were advancing rapidly, as were (albeit more slowly) those of specific output. Gas turbines were only beginning to appear on the technological horizon, a trend that both America and Japan were late in catching.

- **Aeronautics.** As pointed out earlier, the frontiers of feasible airplane performance advanced remarkably in the 1930s. This was the product of a sustained burst of great creativity in the associated engineering sciences which began early in the century and finally began to reach engineering practice in the late 1920s. These advances were to continue right through World War II and up until about 1960.

- **Electronics (radio).** The technology complex we think of as *electronics* was more often thought of as *radio* in the 1930s. Radio was the first electronic technology of wide social and economic impact and its rise stimulated the development of much of the electronic technology which later found other application. In certain contexts people also spoke of electronics technology in terms of (non-power) *electricity*. Like ICEs and aeronautics, radio/electronics had already made a great mark on the world but was still changing very rapidly.

Omitted from this list are some other very important complexes such as the automotive, marine, chemical, electric power, and metallurgical technologies. These were less dynamic in the 1930s and/or not of such direct military importance as the primary three.

The technology of nuclear weapons is in a class of its own, having been almost entirely a product of the World War II era itself, and thus not a part of the story of interwar transformation proper. The U.S. employment of atomic bombs in 1945 certainly seems to have shortened the war by some unknowable but probably non-trivial amount, and thus to have saved many lives, particularly Japanese lives.[268] But nuclear weapons did not otherwise exert any influence on World War II.

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[268] This is a controversial position, as indeed any position on this subject must be. I am persuaded by the arguments made by Sadao Asada in "The Shock of the Atomic Bomb and Japan's Decision to Surrender—A Reconsideration," *Pacific Historical Review*, Vol. 67, No. 4 (Nov 1998), pp. 477-512.

In search of asymmetric advantage

The United States was among the leading nations in development and application of each of these primary technology complexes. Japan had built high-quality technical capabilities in each, as we have seen. After defeat had eclipsed ambitions of military expansion, Japanese engineers applied their abilities to develop technical and economic niches of outstanding excellence and commercial viability which they subsequently broadened greatly, in a recapitulation of the strategies that had earlier enriched America and Germany, among others. But before and during the Second World War, Japan's technical and industrial capabilities – however excellent in quality – were inadequate to bring it to a position of broad leadership in any of the primary technological complexes.

The Japanese military could draw on their country's limited but high quality technical resources to create specific narrow areas of technological excellence and even dominance. In the atmosphere of the 1930s and early 1940s there was no limit to the capacity of the services to command such resources as the nation could provide. Or, rather, the limit was only one of their own understanding and imagination – a very serious limit, as it proved. In cases where the military had the necessary technological vision they were able to achieve some very fine results, as the cases of the IJN's torpedoes and early-war aircraft attest. In other areas, such as radar, lack of vision led to neglect of important opportunities that lay open to them.

In the 1920s and 1930s, when defense was far from the forefront of the minds of the great majority of Americans, the U.S. military was in a somewhat analogous position. The technical and industrial resources it could command were limited, but substantial. The services sponsored some strictly military technology developments and in some cases achieved excellent results, as in radar. They also benefited, to a far greater extent than was possible in Japan, from civilian developments that could be bent to military ends – Diesel engines developed for locomotives as well as submarines, aircraft engines developed for commercial transports as well as bombers, FM radios

developed for police-car communications as well as tanks, and others.

In both nations, military decisions on technology and its development were influenced strongly by officers with technological interests and training. In both, these officers tended to be more common in the navy, although certainly not absent from the army. In the U.S., civilians employed by the services in purely technical capacities also had a certain influence, which made itself most evident in radar.

In the United States, technology's great economic importance and hold on popular imagination created the potential for the technology community to exercise significant political influence, abetted by the pluralistic and polycentric nature of the nation's political institutions. As war approached, suitably-placed individuals within the community became both alarmed by the nation's lack of military strength and energized by the prospects for furthering technology-oriented political agendas. Led by electrical engineer and academician Vannevar Bush, they formed the NDRC and coordinate institutions, which technologists employed not only to serve the technology needs of defense but to play a strong role in determining them.[269] Comparable developments had already taken place in Britain, and may well have helped to inspire Bush and his collaborators. In Japan, where science and technology sat below the political salt, no such arrangements were possible.

It is often argued that "military requirements" for technology ought to be exclusively in the hands of officers on the grounds that only they can know what is truly needed. Japan went beyond this to insist that only line officers, lacking much technical expertise, could determine needs. Generally this brought the IJA and IJN equipment very well suited to executing their existing doctrine. Where doctrine made no place for an innovation, it did not flourish.

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[269] It is with due gratitude and respect that I acknowledge that the institution for which I work, the CNA Corporation, is among the many that owes its founding and position to the efforts of Dr. Bush and his colleagues.

Japanese officers often were very innovative in doctrine – the navy's doctrine for attacking an approaching battlefleet in depth using a wide variety of means serves as an example. They were well able to envision and enunciate requirements for extensions to existing technology in order to implement their doctrinal innovations. Thus the navy demanded and got very superior torpedoes and large quantities of optics the equal of the world's best in order to help it outrange the enemy and deliver night attacks. But knowing little of the new developments in electronics they did not envision radar or understand how very valuable it might be. And so radar was not pursued even though the nation had the necessary technical capabilities.

Nor were their requirements tempered by little-understood considerations of economy or industrial feasibility, nor even of logistical supportability. If their requirements resulted in 12 different and non-interchangeable kinds of ammunition for aerial machine guns where the U.S. got along well with 3, what of it? In the U.S., the experience of World War I had prompted the services to develop expertise in logistics support and its industrial aspects, but Japan had no comparable stimulus. In the U.S., manufacturers had the political position to insist on consideration of their needs and insights, but in Japan they did not.

The pluralism of the U.S. approach entails some seeming inefficiencies. Surely we could get along with fewer models of automobiles and televisions, assembled from a smaller list of parts. And many innovations, military and civilian both, are found not to have repaid the cost of their development. But if there were inefficiencies in development of technology for World War II they were generally of a nature that the nation could well afford to bear.

These interlocking strengths of U.S. technology and technological industry presented Japan with a dilemma in seeking to transform its forces, for how could it find an advantage that its opponent could not readily trump? A partial answer lay in secrecy, and the Japanese military – particularly the IJN, with its reliance on technology – went to extraordinary lengths to conceal its advances. In this they benefited from the unwitting cooperation of the U.S. and Britain, both

slow to recognize developments (such as oxygen torpedoes) that failed to fit their own models of doctrine or technological feasibility, or which violated their expectations regarding Japanese capacities. But this gave the Japanese only limited help in areas such as carrier aviation which the U.S. independently pursued.

Immaterial advantage

So the Japanese services depended greatly on superior tactical doctrine and training, to be executed by troops imbued with superior martial spirit – *seishin* – to make good material deficiencies. This was equally so of both, although the reliance was more exclusive in the IJA's case.

The IJA and IJN sought vigorously for asymmetric advantage through transformation. They found it in secrecy-protected niche technological innovations and in *seishin.* Their technology efforts were hindered by too-exclusive direction by military officers with inadequate technical sophistication. But even at best these efforts would have formidable competition from the immense scope and depth of U.S. technological and industrial resources. In the period prior to 1940 this U.S. potential strength was somewhat hindered by excessively narrow direction by our own non-technical military people, as well as by military budgets no larger than Japan's. Nevertheless, even optimum use of Japanese technological resources probably could not have conferred very much greater asymmetric advantage on its forces unless the U.S. had fumbled a good deal more seriously than in fact it did. *Seishin* and thorough preparation could and did provide some further initial advantage, but not enough to carry Japanese forces to more than a few months of victory.

Japanese officers were well aware of how the "primitive" but hardy and warlike Mongols had ridden in off the steppes to defeat the very advanced – and technologically sophisticated – civilization of China in the 13th century. They imagined they could do the same. But the Mongols, primitive as they may have been in some respects, had gained major technological advantages over China, advantages which played a very important role in their conquest. Modern

America's technological and industrial command was comprehensive in a way that ancient China's had not been, nor even approached. The U.S. military fell a good deal short of fully exploiting this advantage, but not nearly short enough to allow Japan's martial ardor to close the gap.

How fundamental a transformation?

To optimally have transformed its forces to fight the United States, Japan would have needed to integrate its armed forces sufficiently to avoid serious waste and overlap, develop mastery of operational movement and logistics, secure its supply lines, build deep stockpiles of critical raw materials, and prepare its military leaders to make highly effective and imaginative use of the technological and industrial strengths the nation possessed. We cannot know whether this would have sufficed to wring some sort of victory from a conflict with the U.S., but it clearly would have improved Japan's odds.

But before the Japanese military could have accomplished or even conceived of such a transformation it would have had to transform its own very nature as a social and political institution. It is surely open to question how this might possibly have been accomplished. Moreover, had the services somehow managed so thoroughly to recast their essential nature in the mold of rational modernity, we must wonder how it would have affected their whole outlook. Would they not then have been prepared to recognize that Japan had much better options – indeed had few worse – for establishing itself as a dominant regional power than a high-stakes gamble on a war with a nation of far greater potential strength?

For, needless to say, had Japan so transformed itself and its military, it would have taken no comparable exertions of social-political revolution on our part to have opened the gap once again. Having embarked on war, Japan was in the position of a poker player holding a weak hand who faces an opponent with a very strong one. If it was not to fold it could only bluff, but such a strategy offered no hope unless the U.S. played its hand quite badly.

Ultimately, Japan confronted a United States superior not only in material and economic strength but in social modernity. It seems to be characteristic of nations that seek to build their own strength that they tend to shy from the full implications of the social modernization that is its price. (This is scarcely surprising – we see, after all, many people and institutions who find important elements of rational modernity very painful and alien, even in our own society.) This places very significant limits on the military strength the reluctant modernizers can develop. But their psychological and social defenses against the threat of modernity tend to make it the more likely that they will try us in arms.

Glossary

AA	Anti-aircraft [gun]
AAF	Army Air Forces
ASW	Antisubmarine warfare
BUC&R	Bureau of Construction and Repair
BUENG	Bureau of Engineering
BUORD	Bureau of Ordnance
BUSHIPS	Bureau of Ships
COMINT	Communications intelligence
CWS	Chemical Warfare Service
DCA	Defensive counter-air
DF	Direction finding
FDR	Franklin D. Roosevelt
FM	Frequency modulation
HF	High frequency [radio]
HFDF	High frequency direction finding
IJA	Imperial Japanese Army
IJN	Imperial Japanese Navy
LSD	Dock landing ship

LST	Tank landing ship
NACA	National Advisory Committee for Aeronautics
NDRC	National Defense Research Council
NRL	Naval Research Laboratory
OA	Operations analysis
OCA	Offensive counter-air
PPI	Plan-position indicator
RADM	Rear admiral
S-Band	Radar band – frequencies in vicinity of 3 GHz
SIGINT	Signals intelligence
UHF	Ultra high frequency [radio]
USAAC	United States Army Air Corps
USAAF	United States Army Air Forces
USMC	United States Marine Corps
USN	United States Navy
VADM	Vice admiral
VHF	Very high frequency [radio]
X-Band	Radar band – frequencies in vicinity of 10 GHz

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