Technological Change and the U.S. Navy

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In 1904 British First Sea Lord Admiral Jackie Fisher, proponent of the dreadnought battleship, stated that ship design must be dictated by strategy. Fisher's observation seems simple, yet on this side of the Atlantic it would have been inflammatory. American naval engineers would have considered it an indictment of their independence. Line officers would consider it supportive of their efforts to rein in naval engineers who had too much control over the technological basis of the naval profession.

It seems a fairly forthright rule that naval engineers should create technologies that answer the mail and follow the service's chosen strategy. In 1904 the US Navy embraced an unambiguous strategy of guerre d'escadre — fleet vs. fleet action based on the battleship. Many line officers believed the natural evolution of the battleship to be restrained by naval engineers working from within their politically powerful technical bureaus. In a little over a decade, rivalries between engineers and line officers would be overshadowed by the challenges posed to the status quo by the submarine and, to a lesser extent, aircraft.

As a historian I caution people on the depth of the lessons of history. However, there are definite insights that the history of twentieth-century naval technology can offer into the near future of the US Navy. Today's navy, like the navy of 1904, has one strategy: power projection from the littoral driven, in part, by the absence of a viable naval threat. After World War I, US naval strategy remained guerre d'escadre. Maintaining control of the seas, which typically involved defeating an enemy navy, seemed to be something that might be accomplished using alternate technologies such as aircraft and submarines. Laying aside the seemingly myopic nature of today's littoral warfare strategy, there seem today to also be alternate technologies with the potential to get the job done. The navy's current technological exemplar, the aircraft carrier, with its supportive infrastructure, is facing questions within the upper levels of the Department of Defense about its continued viability.

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For any institution, positive technological changes are those which increase its capabilities. One can characterize this type of change as positive, or perhaps more colloquially, as innovative. It is difficult to quantify what is innovative. For progressives, innovation often has tended toward the revolutionary and has not merely been an evolutionary refinement of the status quo. More often than not, revolutionary technological change is the extreme exception to what has commonly occurred.

In assessing technological change within the US Navy, I employ the overworked and hated term, "paradigm." I am fond of extrapolating from historian Thomas Kuhn's original work regarding scientific paradigms. Thirty years ago Kuhn argued that much of the day-to-day work in science merely seeks to define further the prevailing theory within the discipline. Kuhn's concept of scientific revolution — or paradigm shift —theoretical framework is the byproduct of unexplained anomalies. These anomalies arise from disparities between the day-to-day results of normal scientific practice measured against the governing theoretical framework.

In my work, I have drawn a parallel between scientific theory and strategic philosophy. A shift in strategy follows recognition of an anomaly within the existing strategic framework. In other words, there is a perception by some practitioners that the existing strategic theory is flawed. The search then begins for a replacement. A good example was the United States's shift around 1890 from a continentalist naval strategy based in commerce raiding to a maritime strategy of guerre d'escadre based on the battleship. Quite simply, commerce raiding was the strategy pursued by weak naval powers and one unsuited for America's role as a nascent world power.

I also prefer to view the naval profession in the terms developed during the

1930s by the Viennese philosopher, Ludwig Fleck. Fleck’s concepts are especially valuable in describing the naval profession’s intellectual and social dynamics, including the technologically-defined subgroups within the post-1918 naval profession: aviators, submariners, and surface ship sailors. These have been characterized as lobbies or factions, but Fleck's definitions of a *thought collective* as “a community of persons mutually exchanging ideas or maintaining intellectual interaction” providing the “special ‘carrier’” for the *thought style*, which he defined as the “given stock of knowledge and level of culture.”

Modern militaries are technologically-based professions. Modern war fighters identify very strongly with the technologies they operate and possess specific thought styles. Their identification with their technologically-based thought collectives is almost tribal. Ask an aviator if he’s a pilot and he or she won’t just say “Yes” — because aviators like to talk about themselves — but usually will go on and talk about what type of aircraft he or she flies.

In addition to this Kuhnian framework to analyze shifts in strategy and thought collectives and thought styles to characterize the various subcultures of the navy, we need an appropriate framework to deal with the process of technological change. There are two opposing historical models for technological change: technological determinism and social constructivism. Social constructivists consider social (environmental) issues, which tend to be stable rather than revolutionary, as governing the process of technological change. Within this model, acceptance of a dynamic and potentially revolutionary technology — even one with such a clear military use as a Klingon cloaking device — would be not be guaranteed unless it was accepted by the social group.

Conversely, technological determinism has new technologies being the primary causal agents for change. The relationship between military technology and strategy, for example, has been most often portrayed as cause and effect. As with most unprovable, social-science theories, both technological determinism and social constructivism have pluses and minuses. The history of U.S. naval technology since the Civil War includes incidences when either social factors or “soft” technological determinism based in military utility, have been more valid. The ascension of steam propulsion beginning during the Civil War, the replacement of turboelectric propulsion by gear reduction during the 1930s, the aircraft carrier’s replacement of the battleship, and the cruise missile, all typify technologies that overcame the social forces trying to shape or marginalize them. Conversely, the development and adoption of the turboelectric drive for our 1916 capital ships, the rejection of Admiral Zumwalt's small sea-control carrier, the exile of the navy's hydrofoil program, and the flash-in-the-pan arsenal ship, all embodied the power of contextual, or social forces, to shape acceptance or rejection of technology. Additional examples can be found in the case of the interwar submarine, forced to serve guerre d'escadre, as well as the airplane and airship and their service to the battleship technological paradigm.

Military historians, and many authors in the Naval Institute *Proceedings*, have succumbed too frequently to technological determinism, making technology an exogenous factor — a "black box"— that has guided the evolution of the military arts. A good example is noted historian Martin van Creveld whose 1989 book, *Technology and War*, reads like a biblical account in which the sword begat the musket, the musket the cannon, and so on down to nuclear weapons. Such interpretations wrongly ignore any cultural or social framework for technological innovation, development, cultivation, or rejection.

Within the context of the modern Western military experience — and by modern I'm referring to the time since what is commonly referred to as the industrial revolution — change, rooted in science-based engineering, has been overwhelmingly evolutionary in nature. As in some countries where political coups merely involve the same principal actors merely exchanging roles, real revolutions — and changes in power — have been few in number. One would not know this due to the ease with which the term "revolution" is bandied about. The basic question revolves around how the term revolution is defined. If a new technology has no appreciable effect on shifting the underlying strategic philosophy or basic approach to the prevailing military practices it is hardly revolutionary. I would encourage you to think about this the next time you hear the oft-bandied term "Revolution in Military Affairs" or recall the much-acclaimed "technological revolution" for the navy touted during the early 1980s. Are advances in information processing or technological refinements truly revolutionary or do they merely allow the navy to accomplish the same strategic goals and tactical missions by doing the same old thing, just a little faster?

One of the best and most defensible models for technological change would be evolutionary theory. Evolution is continuous, and on a macro-historical scale, discontinuities (or revolutions) have been rare. Fifteen years ago, historian Robert O'Connell considered three twentieth-century technologies as deserving of the label "revolutionary": the airplane, the submarine, and nuclear weapons. Will more be added within the next fifty years? Certainly. The field of information warfare is certainly a candidate. Artificial intelligence, uninhabited aerial platforms, and weapons systems that remove the human face from a significant percentage of warfare will probably be others.

All new technologies have the potential to affect change. For technological societies, such as modern militaries, new technologies can be quite destabilizing. As result, military professionals — especially the members of the professional hierarchy — have approached new technologies with caution.

New technologies have the potential to enhance the institution, to have no appreciable effect, or to challenge the status quo and possibly damage irretrievably the institution and its members.

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New technologies (and ideas) have been encouraged or buried in accordance with the filters defined by the values of the military profession. These filters are rooted in the strategic paradigm to which the profession adheres and in the warrior ethos, and its values, which members of the profession embrace. Filtering out undesirable technologies was easier for the military profession prior to World War II. One thing the Second World War did was educate military officers that money spent in support of theoretical and applied scientific research often resulted in extremely useful weapons and sensors. Radar and the proximity fuze are two very prominent examples from outside the Manhattan Project. The creation of a growing, and increasingly complex relationship among the military, industry, and academia as the Cold War progressed, placed some stress on the military's paradigmatic filters. With the amount of money involved, the widespread funding of research, and the early Cold War shift toward strategic experts — the National Security Council and various advisory boards — it was not so easy for the military to control the path of technological development and selection to just that which fit senior officers' concepts of the proper way to fight.

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In my work, I have tended to follow a third, more middle-of-the-road theoretical framework for technological change evolved from historian Ed Layton's concept of a technological paradigm. A technological paradigm refers to a preeminent technology that is supported by a strong intellectual and cultural framework. Think of this in terms of a dominant weapons systems. This dominant—or exemplar—technology is supported intellectually by the prevailing strategic philosophy based in the expertise of the social group (military officers). The preeminent technology is supported by lesser technologies that are arranged into a supportive technological hierarchy. The dominant technology is also supported culturally by all the resources available to the military hierarchy in regulating their professions: education, training, and tradition.

Preeminent technologies — think in terms of battleships or aircraft carriers, or for the Soviets, submarines — also have what is termed "technological momentum" and "technological trajectory." There's nothing mysterious about technological momentum. I doubt if anyone in this room has not seen or felt the effects of a project that seems to take on a life of its own, for better or worse. Technologies are no different and technological systems usually have even a stronger momentum than individual, non-systemic technologies. If a technology is perceived clearly as useful, that is, it is in agreement with the values or mission of the social group, it will become entrenched. A good example of the power of technological momentum was the strategic defense initiative of the 1980s. SDI combined a broad coalition of political and economic interests with an organized bureaucracy to produce significant momentum for the program. Opponents of SDI overcame this momentum only when the Soviet Union no longer provided a sufficient military threat to justify SDI.

The concept of technological trajectory is related to technological momentum. The selection of new technologies is governed by their agreement with the governing technological paradigm rooted in a preeminent artifact— such as a navy built around battleships, a mechanized army based upon tracked combat vehicles, or an Air Force built around stealth bombers. All new technologies considered for adoption must be an agreement with the dominant technological paradigm. Technologies which challenge the professional, intellectual, cultural, and social status quo have little chance of seeing the light of day without external support. This was certainly the case with the cruise missile which posed a direct threat to the aviation navy prior to the Persian Gulf War.

Technological trajectory, quite simply, forces engineers and innovation within the box defined by those in power. It also involves the accretion of lesser, supportive technologies to support the preeminent artifact and the status quo

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Arguably, military forces have made use of artifacts — weapons — since before the Iron Age. The development of particular warrior ethos have been linked to the weapons their members use. A new weapon that enhances the ethos, for example, a sword made of bronze rather than iron, will be adopted readily. However, weapons that challenged the values of the prevailing warrior ethos have often been ignored. The Mamelukes believed gun powder weapons violated their warrior ethos and spurned them. In 1516, they were crushed by the Turks who had no such compunction.

With the exception of a few periods within pre-industrial history when truly innovative new military technologies have been developed — gunpowder weapons being a good example — military strength has been quantitatively defined. The force with *more* archers, cavalry, cannon, ships of the line, battle-ship, aircraft carriers, etc. had been able to prevail in war or to enforce its will through threats of military action.

Entrenched warrior societies have been skeptical of new technologies and this skepticism increased as the rate of technological development quickened in the wake of the Industrial Revolution and the later rise of science-based engineering during the 1870s. Technological innovation, by necessity, has fallen to the weaker adversary who cannot engage in a direct, quantitatively-based type of warfare with a more powerful enemy. The innovation demon-strated by the Confederacy in its coastal defense — submarines, ironclads, and mines — is a good example.

One option for military hierarchies is simply to ignore technological change. If warfare remains within a common framework, one in which all the combat-ants base their war fighting on the same technical foundation, military strength can be defined quantitatively. International naval competition during the battleship era was a good example of this. Historically, defenders of the status quo have rejected radical technological innovation in favor of non-threatening, symmetrical technological responses (tank versus tank, battleship versus battleship).

Intercultural and technologically discontinuous warfare, however, can shatter an existing, traditional, sociotechnical framework (someone playing by different rules with different technologies). The victories by Portuguese "Atlantic" style ships over Moslem galleys and smaller sailing ships off India in 1509 joins the Mamelukes as a good example.

A second option for hierarchies chary of new technology is to try to control the course and rate of technological change. This is what some American naval officers sought to do, without success, after the Civil War.

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Since you are engineers and the creators of artifacts and technological systems, I would expect you to think that I am painting a rather dismal picture. Why can't promising new technologies burst forth into the light — in a triumph of technological determinism — where they will be acknowledged, accepted, and change ship design or naval warfare forever?

Perhaps an example using the one of the most efficient weapons technologies in history might be useful. The history of the machine gun illustrates how members of a dominant, long-entrenched military society, based in a particular warrior ethos, reacted to an innovative and qualitatively-superior technology.

The machine gun was very successful in supporting European imperialism in Africa, the machine gun became *too* much identified was colonial warfare. The military effectiveness of the machine gun was largely lost within European armies whose hierarchies were dominated by cavalry officers drawn from the aristocracy. Like the Mamelukes, European cavalry officers had a very strong warrior ethos based on traditional warrior traits: personal courage and honor coupled with a class disdain for books, things mechanical, and anything smacking of intellectualism. Their technological paradigm was based in cold steel: the sword, saber, and lance.

For the British, the Anglo-Boer War at the turn of twentieth century, came as a shock. British forces in Africa were not fighting indigenous warriors, such as Zulus or Dervishes. Rather, they were fighting people of European descent equipped with modern weapons — including what would be the two biggest killers during the First World War: the machine gun and breech-loading, steel artillery.

As Canadian historian Tim Travers recounted in his book *The Killing Ground*, the initial reaction of British army officers to the South Africa war was shock. The practice of warfare rooted in the neoclassical warfare of the eighteenth century was in danger of being swept away. The first reaction was denial. What the British army experienced in South Africa was an aberration. The terrain and climate were to blame. Nevertheless, a few officers continued to sound warnings that a new, machine-based lethality had entered the battlefield. However, the problem with warnings in peace time is there is no unbiased framework by which they can be measured. What of war games you might ask? Well, field exercises, or war games, like experiments, can be set up to achieve predetermined results, or interpreted, consciously or unconsciously, to arrive at the results those in command prefer.

A wonderful example took place within the British Royal Navy during a pre-1914 exercise. A submarine — a devilish, sneaky, and ungentlemanly weapon — successfully attacked a battleship. The battleship admiral's signal to the submarine captain was dismissive: "You be damned!" I recall a similar incident over a quarter century ago when my old destroyer sank the nuclear-powered aircraft carrier *Enterprise* in two of the three phases of an exercise. Despite umpire agreement with our successful attacks, we were informed later that the final exercise report did not mention them. I assume the admiral who approved the report had a broader view of the exercise and had valid reasons to discount our success. Or perhaps he was just partial to aircraft carriers and *knew* that a nuclear-powered supercarrier as titanic as *Enterprise* could not be sunk by the likes of us. It was our turn to be damned!

Field exercises do not possess the experimental rigor of a modern laboratory. War, however, acts as a final, and impartial, arbiter. Other peoples' wars have been touchstones for modern military professionals. In 1904, Japan and Russia went to war and European military attaches went to watch. The Russo-Japanese war included widespread use of all the tools of modern industrial land warfare available at the time: modern artillery, machine guns, barbed wire, complex fortifications, trenches, and large numbers of combatants. The problem was that the European observers — members of their own warrior thought collective — saw what they wanted to see. As historian Sir Michael Howard has pointed out, the Japanese succeeded, after many bloody failures, by shifting from large-scale, mass offensives to effective small unit infantry tactics — the same tactics, with variations, employed successfully by the

Germans in the spring of 1918. In general, the word sent back from the war was that the Japanese prevailed because of their adherence to a disciplined, offensive spirit that refused to be stopped by losses. It was Japanese courage and will power based in the effective *and* offensive use of the cold steel of the bayonet that allowed them to prevail in modern, industrial war.

The lessons of the Russo-Japanese War seemed quite clear and comforting: the familiar mode of warfare was still viable. Modern industrial war would indeed resemble South Africa. However, it was winnable if an army had the will to control the battlefield through offensive actions based in manly courage, virility, and discipline. This was consonant with warfare that stretched back to the medieval concept of combat as God's justice.

The Germans, with a more pervasive technological culture than the British, grasped the new machine-based nature of the battlefield early in the war. Chief of the Imperial German General Staff Von Falkenhayn's effort to use the new killing technologies to bleed the French at Verdun reflected that. Although the British came to embrace the concept of human wastage reports during the last two years of the war, Field Marshal Haig still held his cavalry close for the final dash to Berlin and victory using the lance. It is not surprising that the British army had no machine gun doctrine until 1918.

A minority of British officers subordinated the traditional human-centered battlefield to one dominated by the new killing technologies. However, the majority of officers favored the offensive at all costs. This was a view of warfare in which the disciplined soldier still dominated the battlefield.

The Russo-Japanese War also influenced the subsequent debate over how the US Navy should execute its War Plan Orange against Japan. The war also provided Commanders William Sims and Bradley Fiske — ardent supporters of the all-big-gun battleship — with ammunition to defeat the great Alfred Thayer Mahan and his advocacy of the status quo of predreadnought battleships with secondary gun batteries.

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During the First World War, the airplane was far from being a mature technology. After the war, aviation became a technological anomaly that challenged the existing military technological paradigms of land and sea warfare.

The conclusion of many was that the future of land warfare was rather limited. The killing machines ended the era of maneuver warfare on the ground. The only effective maneuver warfare would occur in the skies.

Aviation advocates, such as Billy Mitchell, also predicted that aviation could replace the navy as the country's first line of defense. Mitchell's claim that a $10,000 bomber could sink a $10 million battleship was well received, especially by Republicans who were anxious to reduce federal spending in their efforts return the country to normalcy after the 1920 election. After the First World War, aviation benefitted from a very supportive, and hopeful, political and social framework.

The navy's response was interesting. Our popular historical legacy links the battleship with obsolescence and equates battleship admirals with dinosaurs. In reality, the naval hierarchy was quite supportive of aviation. In fact, the number one shipbuilding priority from the office of the Chief of Naval Operations in 1919/1920 was airplane carriers. To defend itself from criticism that it was against aviation, the navy lobbied Congress for legislation to build upon the work of Rear Admiral David W. Taylor and the Bureau of Construction & Repair and to create the Bureau of Aeronautics. The first chief of the bureau was Rear Admiral William Moffett who, in 1916, had advocated construction of the largest battleship possible in an article prepared for the Naval Institute's annual essay contest. Like his fellow officers, Moffett was an adherent to the battleship-based strategy of guerre d'escadre and perceived aviation as a technology that would be subordinate within the navy's battleship-based technological paradigm.

The 1921 bombing trials, during which several old battleships were sunk by aerial attack, provided aviation enthusiasts with wonderful publicity. By 1924 things had reached the point that the secretary of the navy ordered the General Board of the Navy to conduct hearings into the navy's technological hierarchy and strategic philosophy — rooted in the battleship — prior to submitting his annual budget. The 1924 Special Board hearings were confidential and a broad variety of experts appeared ranging from Billy Mitchell to the leading aeronautical experts from MIT and Stanford. After obtaining thousands of pages of testimony, the General Board reported that the battleship was still the proper basis for American naval strategy.

In their testimony before the Special Board, naval aviators reflected their philosophical identification with the normal practice of the battleship-based strategic paradigm. Rear Admiral Moffett, chief of the Bureau of Aeronautics, typified the battleship thought style, characterizing aircraft at sea as "auxiliary to the fleet." Perhaps recalling his own fondness for big-gunned battleships and his Medal of Honor-winning shelling of Mexicans at Vera Cruz in 1914, Moffett's ultimate expression was his statement to the Special Board that "Aviation is a gun; it is a form of a gun." The Bureau of Aeronautics' Lieutenant Commander Marc Mitscher, who would later achieve fame as a commander of aircraft carrier task forces against the Japanese during World War II, also testified from within the battleship framework. Basing his conclusion upon bombing and gunnery exercises conducted since 1922, Mitscher told the Board that gun fire was more effective than aerial bombing.

Perhaps the most visionary testimony came from recently-retired Admiral William Fullam, whose career had spanned the battleship era and who testified "My whole heart was given to the biggest gun and the biggest ship that could be conceived." Fullam conceptualized a "'Three Plane Navy' with forces on the surface, below the surface and over the surface." Using the submarine as an example, Fullam accused the navy of learning nothing from the World War since antisubmariners within the Navy Department had prevented the director of submarines from testifying before the Senate Naval Affairs Committee in February 1921 regarding the need for submarines. In addition, Secretary of the Navy Josephus Daniels's appointee as chief of naval operations, Admiral Robert E. Coontz, had deleted all submarines from the naval appropriations bill.

Although critical of the limited naval appropriations of the Harding and Coolidge Administrations, Fullam argued that whatever funds were given to the navy should be used to develop the three-plane navy to its fullest efficiency, so that all technological factions could work together like a Nelsonian "band of brothers." Rejecting the singularity of the battleship thought style, Fullam demanded the creation of a "*three-idea* Navy" as it would win out over a "one idea navy every time." According to Fullam, "The nation that first does this, that first solves that very complicated problem, will win the next war." Fullam was ignored.

Critics, such as Billy Mitchell, painted the navy report, and the continued dominance of the battleship, as a whitewash. Yet Mitchell and other critics were wrong. While a promising technology, aviation capabilities could not match Mitchell's predictions. Contemporary aircraft did not yet have supercharged engines and were thereby limited in altitude, speed, and carrying capacity. It was doubtful that they could carry bombs large enough to penetrate the armor of modern battleships. Also, the aircraft could not fly above 10,000 feet. Live-fire exercises conducted by the navy were yielding an amazing 75 percent hit rate for antiaircraft fire from battleships against towed aerial targets. In addition, the hit rate for bombing attacks against radio-controlled target battleships was abysmal. The real clincher was the prediction by aviation industrialists and aviation engineers that the present capabilities of aircraft — speed, service ceiling, bomb load — would not increase by more than 30 percent in the future.

Within a few years, aviation broke through the 30 percent technological ceiling predicted in 1924. Many aviation supporters presumed that naval aviation and the aircraft carrier would be the basis of future naval power. Naval aviation was now a presumptive anomaly to the dominant battleship-based technological paradigm. However, naval aviation was unable to escape its subordinate role within the battleship-based technological hierarchy. This was due to several factors: the strength and resiliency of the superdreadnought battleship, the inability of aviation to act at night or during bad weather, and, most importantly, the absence of aircraft up to the job. By the late 1930s, the most effective technology supporting the presumption of aviation ascendancy was the dive bomber. It offered tremendous potential but now until 1941, when the first dive bomber squadron equipped with the all-metal, monoplane SBD Dauntless dive bomber became active, was there a real possibility for naval aviation to demonstrate its power.

Interestingly, Franklin Roosevelt, a strong supporter of the navy as part of the New Deal, was a supporter of the battleship. When international naval arms treaties ended in 1937, Franklin Roosevelt, using the tremendous power given to him by Congress regarding naval construction, oversaw the authorization for the construction of seventeen new super battleships prior to the attack on Pearl Harbor.

Within popular culture, Pearl Harbor is portrayed as a watershed event in terms of a shift from the reactionary battleship era to the forward-thinking, aviation-based navy that would win the Second World War. Such simplistic interpretations ignore the reality of the Pacific Ocean War and what the navy was thinking in terms of its force structure, tactics, and strategy in 1940 and 1941. In 1941, the naval hierarchy had moved beyond the battleships which would be destroyed at Pearl Harbor. The future of the navy lay with the concept of the fast task force composed of the new fast aircraft carriers *and* fast battleships authorized since 1937. If war came, the aircraft carriers would rule during the day in good weather and the battleships would rule the night and periods of bad weather.

With new aircraft, and unfettered by peacetime limits, naval aviation went from being a presumed challenger to the battleship to a fully competing technological paradigm. After VJ-Day, there were no battleships left in the world to fight. The navy had a hard enough time justifying its existence in the new atomic age but the aircraft carrier, with its 200-plus mile strike range eclipsed the 20-mile offensive range of the battleship. And the aircraft carrier had the potential to do what a battleship could not: deliver an atomic bomb.

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A recent parallel to the interwar presumptive anomaly posed by aviation involves the presumption of the future ascendancy of cruise missiles and other uninhabited combat aerial vehicles (UCAVs). Like aviation during the 1920-30s, the cruise missile challenged the core warrior ethos of the dominant AVIATION thought collective that ruled the Cold War navy. The cruise missile threatened to make life difficult for the air force as well.

During the Cold War and beyond, the navy has measured its health by the number of aircraft carriers it possessed. Like the earlier battleship navy, the overseers of the naval aviation technological paradigm sought to control the navy's technological trajectory. This involved limiting technologies that would challenge their dominance, such as shipborne missiles like Harpoon and Regulus, while constructing supporting technological hierarchies typified by the *Aegis* air-defense cruisers that fit the aviation concept of war at sea.

Just as during the battleship era, industries wishing to do business with the navy had to fit through the relevant paradigmatic filter. In their early push for the single-seat F-18A strike fighter, McDonnell-Douglas's advertising theme supported the individualist, aviation warrior schema, touting "One Man, One Plane." Senior naval aviators also tried to "spin" popular culture. The 1986 movie *Top Gun* followed hormone-supercharged fighter pilots, led by the charismatic actor Tom Cruise, through their training at the navy's Fighter Weapons School. Once knighted at graduation, these select warriors were sent immediately to an aircraft carrier in the Indian Ocean to handle a "crisis situation."

The modern cruise missile presents the clearest technological challenge to the ascendant position of naval aviation and the Top Gun Club. The cruise missile, along with other uninhabited combat aerial vehicles, portend twenty-first century warfare increasingly dominated by machines with less direct human involvement. At its darkest, future warfare presented in the movie *Terminator*. These technologies also contribute to presumptions that the aviation paradigm is in decline.

Historian Kenneth Werrell has chronicled the postwar history of the cruise missile within the air force, navy, and Department of Defense. Aviators in both services generally resented the missile, denigrated its capabilities, and bemoaned the lack of a pilot able to adjust to the dynamics of combat. Naval aviators perceived the Tomahawk sea-launched cruise missile (SLCM) as infringing on their antiship and land-attack missions. One aviator chief of naval operations berated an officer providing a brief on the early cruise missile: "We already have a cruise missile, it's an A-7 [a single-seat attack jet]. We don't need your cruise missile!" In testimony before Congress in 1973, Secretary of the Navy John Chafee minimized the need for cruise missiles and parroted the 1924 aviation thought style that "aviation is gun" by testifying that "carrier aircraft are essentially 'manned cruise missiles.'"

If it had been up to the navy or air force, the cruise missile would never have seen the light of day. Only the external support from the Department of Defense led to its development.

The Tomahawk SLCM had to wait for the Persian Gulf War for an opportunity to demonstrate its effectiveness. Important Iraqi facilities in Baghdad were protected by an antiaircraft network judged "more formidable than those of any Eastern European target at the height of the Cold War, and seven times as dense as Hanoi's during the full-scale U.S. air offensive (Linebacker) in 1972."

Navy assessments after the Gulf War defended the aviation technological paradigm based on the aircraft carrier and inhabited aircraft. Like submarines and carrier aviation during the battleship era, the 1991 cruise missile was presented as a subordinate technology that allowed the technological exemplar—the aircraft carrier with its air wing—to act decisively in destroying the enemy.

The Tomahawk had other chances to demonstrate its capabilities when the United States launched two air strikes against Iraq during 1993. When Iraq was implicated in an assassination plot against former President Bush in June 1993, no aircraft carrier was available for a punitive strike. The Clinton administration launched twenty-three missiles against an intelligence center in Baghdad.

Cruise missile advocates believe these 1993 strikes marked a new policy consensus to use cruise missiles to prevent political fallout from killed or captured aircrew. This was not the case during early peacekeeping operations in Bosnia where traditional reconnaissance/combat flights were the norm. The loss of one air force fighter to ground fire forced a successful but dangerous combat extraction of the pilot by a marine rescue team in June 1995. Three months later, military operations shifted to thirteen SLCMs launched from the cruiser *Normandy* in the Adriatic. During the spring 1999 NATO air war against Serbia, cruise missiles played a critical, early role.

Like interwar aviation advocates, supporters of the cruise missile attribute the reliance on piloted aircraft in Bosnia not to a "dearth of technology" but to the military's "failure to see the trend" toward stand-off capability inherent in modern cruise missiles. The trend became more visible in August 1998 when the Clinton administration relied solely on SLCMs to strike terrorist facilities in Afghanistan and Sudan. It is unclear if the Baltimore Sun headline —"Navy Fires Cruise Missiles from Arabian, Red Seas . . . *no aircraft were used* "— expressed surprise or merely reported a new era of warfare.

Recent studies within the chief of naval operation's Strategic Studies Group pose additional potential anomalies to the aviation technological paradigm. New technologies under consideration range from improved naval guns with extended range, and possibly hyper-velocity, projectiles; use of uninhabited combat aerial vehicles; and more advanced, and less expensive SLCMs. UCAVs promise to be recoverable, be smaller and take up less deck space, be able to exceed the physiological limits of crewed aircraft, and retain a person in the decision process. The fact that the "pilot" could control the UCAV from a ship or even from a computer in the Pentagon poses a serious threat to the aviation warrior ethos and strikes at the heart of the defining relationship between aviators and their technology. None of this is meant to say that the aircraft carrier is obsolete. However, future carriers like CVX may be carrying very different things than today.

In June 1998, *Navy Times* reported that the navy had placed its new carrier design, the CVX, on hold because of budgetary problems. Expenditure of $3.2 billion on CVX research, development, and design threatened acquisition of the last *Nimitz*-class supercarrier, CVN 77. The CVX design team had promised an innovative new carrier embodying an "architecture for change" to build what Chief of Naval Operations Admiral Johnson told the Senate Armed Services Committee in 1997 would be "the right ship for the second half of the 21st Century." Now, that is quite a statement! Interestingly, the first CVX design criterion, published by the Naval Sea Systems Command on the old CVX web site, was to build a carrier that "maintains [the] core capabilities of Naval Aviation." These core capabilities were not specified but continued reliance on inhabited aircraft to perpetuate the aviation warrior ethos and the knights of the air is a reasonable assumption.

Like the battleship, the aircraft carrier is an extremely expensive expression of offensive naval power. Historian Peter Karsten, writing amid the debate over intervention in Vietnam, questioned why the United States built large supercarriers as opposed to inherently defensive technologies, such as coastal defense submarines. The answer is complex, and part of a debate extending back to the Early Republic, but rests in part in the aviation technological paradigm. A proposal from a few years ago to construct cheap "arsenal ships," carrying approximately 500 cruise missiles, met widespread opposition within the navy and was canceled after Admiral Boorda's suicide in 1996.

A century ago, the steel battleship was the measure of naval power. When the self-propelled Whitehead torpedo — carried on small, fast torpedo boats — threatened the established order, naval hierarchies pursued ways to preserve the battleship's preeminence. Naval architects modified battleship hulls to absorb torpedo hits. Naval tacticians countered the torpedo by expanding the defensive ring around battleships using torpedo boat destroyers. The same ideas of defense in depth, combined with technical improvements, governed later attempts to protect the battleship from submarines and aircraft.

After World War II, the navy created a technological hierarchy to protect the aircraft carrier just as it had with the battleship. Technologies that did not fit the aviation focus were cancelled. Components of the aviation technological paradigm contributed to preserving the new status quo and attempted to relegate counter weapons, and presumptive technological anomalies, to the periphery. Change has, indeed, usually been a slow process.

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In the military arts, a presumptive anomaly has usually required a wartime framework to demonstrate its value and ability to challenge the existing order. This is due to technological momentum, technological trajectory, and inherent paradigmatic inertia. During the late 1930s there was increasing professional awareness of the presumptive anomaly posed by naval aviation. However, the shift to an aviation-based technological paradigm required clear demonstrations of naval aviation's superiority in combat during World War II.

For competitive technological societies such as our modern military services, repression of a new technology is a path fraught with hazards if an effective, anomalous technology is not adopted and finds sponsors elsewhere.

A subtle indication of paradigmatic uncertainty and a move toward the flexible "three-plane" navy Admiral William Fullam advocated in 1924 can be found in the navy's recent rhetoric. In 1997 the naval hierarchy started talking about minimizing the importance of individual technologies (aircraft carriers, cruisers, aircraft or submarines)—termed "platform centric warfare"—in favor of technologically-diverse "network centric warfare."

Today, it seems a broad spectrum of dynamics—from thought styles and professional rivalry to the defense of the dominant technological paradigm from competing technologies — often have clouded military perceptions of which technology is a "winner."

Innovation is not as simple as having a great idea. This is an Institute, and a room, that is full of great ideas. But a great idea must be nourished and protected from ruthless predators as it matures to the point where its worth can be evaluated. Even then, many barriers may have to be overcome.

Midshipmen at Annapolis are told regularly to think outside the box. But as junior officers they will be busy in the box learning their trade and, in the process of becoming senior officers, they can easily accrue the thought style and prejudices of their trade and remain within their narrow, technologically-defined thought collective.

In the broadest sense, the evolutionary model of technological change is quite applicable to militaries: evolve or die. Yet change has come more readily from a setback than from a victory. Prior to the 1789 revolution, the French army redefined itself, solidified the concept of the army division and then the corps, standardized its artillery, and engaged in a vibrant debate that set the stage for Napoleon's victories. All this was a result of France's crushing defeat in 1763. What will it take for us to be viable in 2033? In this dangerous age of weapons of mass destruction, information warfare, and nano-machines can we even survive such a setback?

During its history, Program XIII-A has cultivated an environment that fosters the development of ship designers who have sought to test the limits of conventionality. I can think of no finer legacy than one of dynamic, intellectual curiosity. History indicates that significant external forces act to keep technological innovation within known boundaries. The continuing challenge for the faculty and students of this program is to act aggressively, not to just answer tasking but to provide the technological ideas that stimulate the leadership of the navy to think dynamically and differently about the very serious issues of the navy and its role in our national defense.

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