The Search for Certainty

Remarks for the Defense Technology Seminar
Lincoln Laboratory, 29 March 2007

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We Americans are distinguished from all other peoples on this planet by our command of technology— our mastery of its discovery or invention, our facility with its actualization, and above all, our ability to use it to ameliorate the human condition, and to endow our nation with historically unprecedented moral strength and military prowess. Technology has been the touchstone of American destiny. It explains our past, and it lights our way into the future. Materials, statistics, equations, physical laws, systems engineering…..assured reality. Like most of you, I arrived here wearing a cell phone and carrying a computer vastly more capable than the most powerful machine at MIT when I entered that institution as a freshman in 1943. We are, all of us, in touch with, in the grip of, technology. Technology that knows, remembers, correlates. Technology alluring accessible, even intimate. But….but does it understand?

Had I been asked to suggest preliminary readings for this event, I would have nominated Elting Morison's lectures of the 1950's and '60s, presented in his book Men. Machines, and Modern Times[1], one of the more perceptive commentaries on the interaction of innovative technology with American military institutions. Morison drew inspiration, at least in part, from his great uncle's papers of the previous century, for he one of the first to observe that technology that transforms is inherently disruptive. To quote the elder Morison:

> **"...in many ways the new epoch must open as an era of destruction... both in the physical and the intellectual world, of old buildings, and old boundaries and monuments, and furthermore, of customs and ideas, systems of thought and methods of education... the danger is that the destructive changes will come too fast, and the developments which are to take their place not fast enough. The trouble will lie in the gap between the two..."**

The younger Morison lectured on the impact of the disruptive technology that transformed the U.S. Navy from sail to steam propulsion, especially an initial step that he referred to as "the strange history of the steam vessel *Wampanoag*." Laid down in 1863 to meet the threat of Confederate commerce raiders, this screw-driven, steel-hull frigate set world records for sustained speed on her initial sea trials in February 1868. Her commanding officer for the trials reported her "faultless," and "the fastest in the world." She was, moreover, one of the more heavily armed ships in the navies of that era.

In l869 a newly appointed Secretary of the Navy convened a board of naval officers to assess all steam technology in the operational fleet. The Board's findings[2] enumerated several particulars in which *Wampanoag*'s machinery impaired conventional CONOPS, including a criticism that under sails alone, she enjoyed no advantage in speed, range or maneuverability over the Navy's other frigates. However, the ship's main drawback was that it could not serve the purposes of training or professional development, and was therefore "a sad and signal failure, and utterly unfit to be retained in the service." Allow me to quote the Board's report on that particular:

> **"Lounging through the watches of a steamer, or acting as firemen and coal heavers, will not produce in a seaman that combination of boldness, strength, and skill which characterized the American sailor of an elder day; and the habitual exercise of an officer, of a command, the execution of which is not under his own eye, is a poor substitute for the school of observation, promptness and command found only on the deck of a sailing vessel."**

The Secretary sought a second opinion from two other officers whom he knew had been favorably impressed with *Wampanoag*'s "steady," "efficient," and "easy" performance at sea, but these opined the vessel should be substantially modified because they believed that the Navy no longer had a strategic or tactical requirement for a vessel of such high speed —she would out run the rest of the fleet. Still another group of senior advisors urged the Secretary not to proceed further with steel hulls and steam propulsion, noting that, while ironclads might prove necessary in some ill-defined future contingency, given the availability of eastern timber to build more sailing vessels, risks could be accepted in the interests of the economy as a whole, and the livelihood of eastern shipwrights in particular. The consensus was that the perpetuation of sail propulsion was essential to the Navy's future, and that there was no politico-military justification for radical improvement. *Wampanoag*'s technology was perceived as a direct threat to the maritime culture of its time. The Secretary of the Navy ordered removed from service; the fleetest of the fleet ended its days a rusting hulk tied to a pier in Annapolis. In Morison's view, the *Wampanoag* instance is a prime example of disruptive technology posing a problem that is "not primarily engineering or scientific in character. It's simply human." The US Navy waited twenty years before it brought in the fleet the USS *Philadelphia*, a vessel comparable in battle effectiveness to *Wampanoag*: about the same displacement and speed, but less well armed, albeit more heavily armored.

The lessons for any proponent for a technology, no matter how certain he may be of its maturity, are these:

1. **The American armed services are not likely to adopt a new technology solely on its own merits.**
2. **Novel technology can catalyze transformation, and frequently is necessary for same, but it is rarely sufficient for that purpose.**
3. **Introducing a disruptive technology will succeed only if its impact on service culture is anticipated and provided for, and —as we shall see— those provisions may include strong top-down support within the Administration, and not infrequently, within the Congress.**

Allow me shift focus to the Army. The Army no longer states requirements as goals for technologists, but rather describes capability gaps drawn from systems engineering keyed to doctrine, training, leadership, organization, materiel, and soldiers —the vocalized acronym is dot-lums; often an F for facilities is added, rendering it even more unpronounceable. “Dot-lums” is the Army's mantra for scrutinizing new technology, but the hazard is that DTLOMS can also comprise a conservative litmus test, and a constraint on innovation. Doctrine must be consensual to be effective. Training is the means of developing such consensus. Leadership and Organization must perforce reflect both “D” and “T.” Enabling Materiel, demonstrably cost effective, is essential, and Soldiers are fundamental. Nevertheless, consensual views must be transformed from time to time to adapt to changed strategic, operational or tactical circumstance. The fact is that Army culture has often operated to foreclose new technology that promised significant advances in operational efficiency.

In 1794, President Washington, to free the nation from dependence upon foreign military technology —that year it had purchased abroad seven thousand shoulder arms— set up two national armories, the first at Springfield, Massachusetts, and the second at Harpers Ferry, Virginia. The new nation was on the cusp of the industrial revolution, but those armories operated originally with handicraft, the traditional method of production: one skilled mechanic took nine days to turn out a single smooth bore, muzzle-loading musket of the French Charleville pattern, every part of which he crafted with his own hand and eye. The two armories proved to be quite unequal to arming the nation. The threat of war with France in 1797, followed by heightened tension with England in the following decade, led to hefty Congressional appropriations for numerous penny-packet lots of muskets through standardized contracts to small, commercial foundries in the several states. Among those contracts, however, there was one Boeing-scale aberration: a contract with a young Connecticut Yankee named Eli Whitney for 10,000 muskets to be fabricated using water-powered machine tools to mass-produce interchangeable parts, and delivered in the astonishingly short period of two years. Whitney was well connected in the Administration, and had acquired an aura of technological competence with his invention of the cotton gin, but in fact he was debt-ridden, and had no plant, no machinery, no work force. The Federal Purveyor of Public Supplies found no reason to believe that Whitney had the technology to deliver on his contract. Whitney nevertheless succeeded in persuading the government to overlook delays, and even to advance funding to underwrite what we would term research and development. In 1801 he staged a demonstration for President John Adams, President-elect Thomas Jefferson, and some of the latter's incoming cabinet designees. Whitney showed them a batch of musket parts, and proceeded to assemble a complete firearm from randomly selected parts. Jefferson, who, as American Minister in Paris in the 1780s, had visited an arms manufacturer experimenting with interchangeable parts, became Whitney's strong supporter, as did Henry Dearborn, Jefferson's Secretary of War, who remained in office for the following eight years. In that time, Whitney kept his enterprise alive, and eventually, after the passage of ten years, delivered the final batch of weapons due per his original contract. His cash return was inconsequential, but he had capitalized a novel factory, stimulated competition that caused the national armories to innovate, and indeed, prompted the formation of several new automated arms factories in New England.

When I was in school, Eli Whitney was held up as a paragon technologist, the quintessential inventor-capitalist,[3] but more recent research has shown that "As the star of Eli Whitney has dimmed, other stars have become visible for the first time. Men like [Captain] John H. Hall of the Harper s Ferry armory, Simeon North of the Staddie Hill factory in Middletown, and Roswell Lee of the Springfield armory…Whitney's most important contribution to the American system [manufacture based on interchangeable parts] stemmed not from any technical innovations, but from his active promotion of the engineering ideal of uniformity [of components]. He deserves being remembered as an early master of technological public relations." [4]

I burden you with all this information because mass production of component parts to predictably certain tolerances was absolutely necessary for the division of labor that Adam Smith had called for in his Wealth of Nations, and for the application of the enlightened management prescribed by the Father of System Engineering, Frederick W. Taylor, in his book The Principles of Scientific Management, published in 1911.[5] Remember that Taylor wrote not about technology itself, but rather about organizational and cultural reformation, presenting strong arguments for managerial centralization coupled with worker collaboration, and inveighing against "soldiering" — the latter thrust not to demean professional pursuits such as my own, but rather to urge demise of the Beetle Bailey work ethic that was pervasive among American workmen of his generation. Moreover, consider that the national armories are no more: Harpers Ferry is in the hands of the National Park Service, and Springfield Armory survives as a commercial arms firm located in Geneseo, Illinois. Recognize too that there is strong sentiment in Washington on both sides of the Potomac in favor of commercial contracts to stimulate technology innovation. You appreciate that the Army is progressing from a two-dimensional force to a three-dimensional force. You understand that while dominant firepower remains *sine qua non*, the Army's perception of the way ahead in science and technology lies upward in elevation, bandwidth, and frequency, downward in power consumption, faster in all combat functions, and forward to empower the foremost combatants, all underwritten by a software supported all-encompassing network. These challenges mandate disruptive technology.

Officers of the Acquisition Corps of the Army, now its most numerous branch, will have to live down dreadful mistakes of their predecessors, as well as to cope with contemporary culture and entrenched bureaucracy. In all wars —but perhaps more urgently in Iraq and Afghanistan— the Army exists to project and to support soldiers attempting to control territory and people thereon. Ergo, technology to support that soldier ought to be, but has seldom been, one principal object of Army acquisition. Think of the repeated failures in the past to harness the momentum of American industry to recognize and to address capability gaps faced by soldiers on foot amid a hostile populace.

In 1853, the Secretary of War, Jefferson Davis, testified before Congress against over-reliance on commercial enterprise, pointing out that a soldier in charge of a national armory would have professional incentives to find and to adapt technology to enhance military effectiveness, but that a civilian contractor would, in contrast, be motivated to prolong replication of existing technology: "every change would be to an evil in which he would see increased trouble and diminished profit." Over the next decade, however, Army bureaucracy showed that Secretary Davis was wrong.

During the Civil War (1861-1865), striking the proper balance between in-government and entrepreneurial development had to do with rifled shoulder arms enabling infantry units to deliver volume fire. The Springfield Armory's 1855 .58 caliber rifled musket had up to ten times the range of its smoothbore predecessors, but that piece was muzzle loading, so that maintaining a volume of fire necessitated arraying masses of riflemen vulnerable to artillery and infantry counter fire. In 1860 Christopher Spencer of Connecticut had patented a .52 caliber magazine-loaded repeating rifle, which he promptly offered to the government. The Department of the Navy liked it, and placed a small order. But beyond that success, Spencer's path was barred by BGen James Ripley, Chief of Ordnance, US Army, a thorough-going devotee of standardized simplicity, a system engineer who was prepared to deprecate the field-worthiness of anything more complicated than a club. Ripley had been in command of Springfield Armory when the Model 1855 was fielded. He professed grave concern over Spencer's intricate mechanism, and deplored the baleful logistic implications of any magazine-fed, rapid-firing weapon. Spencer addressed Abraham Lincoln on the matter, and the President, favorably impressed, ordered Ripley to place an order for the weapon. Ripley delayed, determined to avoid the procurement or to reduce its size by any means. By 1863 some Union regiments were buying Spenser's rifle with their own money, and there followed favorable reports on its performance in battle

—e.g., at Gettysburg. Spenser again appealed to Lincoln. On August 18, 1863, Lincoln sent an aide next door to ask Secretary of War Stanton to join him for a shoot in a park near the White House, but Stanton declined. Lincoln remarked, "They do pretty much as they have a mind to do over there," and went out with Spenser to conduct the trial. A board with a bulls-eye was set against a tree, and Lincoln fired seven shots from forty yards, one through the mark, and all within the board. Lincoln presented the board to Spencer, and Spencer presented the rifle to Lincoln. Within two weeks, Ripley was retired. In Sheridan's Shenandoah Valley campaign of 1964, at Waynesboro, cavalry troops under BGen George A. Custer, armed with Spenser's rifle, flanked Jubal Early's veteran infantry blocking the road and railroad through the Rockfish Gap, and routed the Confederates with superior firepower.

In 1862, Oliver Winchester of New Haven, owner of repeating-weapon patents granted less than a year after Spenser's, sent silver-engraved models of his weapon to procurement officials whose knowledge might lead to Army orders. Again Ripley barred the way, although he did buy 1200 rifles for Federal Marshalls. Winchester's weapon, called the Henry rifle after Winchester's chief engineer, was of smaller caliber that Spenser's, but easier to aim because of higher muzzle velocity, lighter, simpler, sturdier, and cheaper — able to shoot every 3 seconds, and to provide a soldier with one round in chamber and fifteen in magazine: a "sixteen-shooter." The Henry rifle became the shoulder weapon of choice in the Indian-fighting army.[6].

After the Civil War Army procurement officers stumbled over more than just shoulder arms: the Army consigned Gatling's gun to the role of direct support artillery, and spurned the American inventors of more automatic machine guns —Browning, Thompson, Lewis, and Hotchkiss— insuring that U.S. soldiers would fight World War I with French and British weapons.

In 1920 Major Dwight David Eisenhower, then commanding the Army's Tank School at Fort Meade, published an article in the Infantry Journal advocating a 15-ton tank mounting a cannon and two machine guns, with a speed of 12 mph across country and 20 mph on road. For his temerity Eisenhower was summoned before the Chief of Infantry, who told him that his ideas were not only misguided, but also dangerous, and that he faced court-martial if he persisted in them. In a classic case of preparing to fight the last war, the Army concerted with Congress a law constraining the systems engineering of tanks: the Defense Act of 1920 mandated that no tank should be capable of a speed in excess of that of soldiers afoot — 2.5 miles per hour. As late as 1939, published Army doctrine stipulated that the missions of tanks were either to move just ahead of infantry to eliminate enemy machine guns, or to attack among infantry to support by fire. In fact, during the years between the World Wars the Army bungled both armor and anti-armor technologies, developing neither a tank capable of deep offensive thrusts, nor an anti-tank gun that could overmatch the threat of enemy tanks. Worse, Army rejection of J. Walter Christie's elegant armored fighting vehicle design forced that inventor to sell his system concept abroad, there to materialize later as threats — German tanks in World War II and the Russian T-34 tank in Korea.

During the Cold War, the Army failed to respond to fifty years of clearly stated requirements to transport overseas combatant reinforcements for NATO by persisting in a fetish-like attachment to cannons, ballistic projectiles, and associated trucks when more effective firepower could have been fielded more expeditiously with a far less burden on deployment and sustainment means. As far as I have been able to ascertain, the technologies inherent in the Multiple Launch Rocket System, or the "rockets in a box" now in firing tests, could have been fielded a generation ago.

And then, to close out the evening, there is the case of the U.S. Air Force. The Air Force was a relatively latecomer to the struggle with disruptive technology. General Billy Mitchell was indeed a visionary, but the World War II Strategic Bombing Survey casts some doubts on the primacy of that mission, and his prophecies that land-based bombers would eclipse the battleship deserve reservations. It seems to me that carrier-based naval aviation, not land-based bombers, wrote finis to battleships, and that it could be argued that had General Mitchell prevailed in obtaining during those inter-war years an air service free of the constraints of Army culture via an RAF-like transformation, U.S. naval aviation might have suffered an atrophy like that experienced by Royal Navy's fleet air arm —the original pioneers with ship-borne aviation. For the Louisiana Maneuvers of 1940, General George C.

Marshall, discovering that Hap Arnold had neither aircraft nor pilots capable of emulating the German *Stuka*, borrowed dive-bombers from Admiral Stark, the CNO. Marshall condoned an agreement between the Army Air Corps and the Army's artillery branch dividing the battlespace into areas reserved for the particular weapon systems of each party, thereby insuring that it would be 1944 before Pete Quesada and J. Lawton Collins worked out effective TTP's for close air support of maneuvering ground forces.

I spent yesterday and the day before with the Army-DARPA Senior Advisory Group, dealing with a recent letter from Chief of Staff of the Air Force proposing that the Secretary of Defense designate the Air Force as executive agent for development, procurement, and operation of all aerial platforms flying above 3000 ft above ground level. The justification was the plethora of unmanned platforms and sensors being procured by the several services, and the need for systems engineering of Intelligencc, Surveillance, and Reconnaissance over the battlefields of today and tomorrow. There was no mention of the fact that no service has yet to field a radar capable of locating and tracking individuals afoot, or that certain sensors aboard platforms operating above 15 thousand feet have a ground sampling dimension of a few inches, capable of detecting enemy activity of prime interest to the foot soldier.

There is a possibly apocryphal story about General Tasker Bliss, Chief of Staff of the Army during World War I, who on his deathbed in 1930 was asked if he had any regrets about his career: the gnarled hands clutched the counterpane, and in a long-unused command voice the old general declared: "I should never have let the bastards out of the Signal Corps."

I too have a regret. I wish Jack Vessey were here tonight to deliver one of his Hittite anecdotes. When Jack became Chairman of the JCS, a friend advised him to drop his custom of reciting in his speeches one or more humorous ethnic stories. In Jack's case, being from Minnesota, these were invariably about Scandinavians. The Chairman decided that thereafter he would talk only about members of an extinct race, the Hittites. With his permission, therefore, I will conclude by telling you about a Hittite housewife, Helga Johannsen, who made an unprecedented trip to a bank to cash her husband's pay check. She held up the check before the teller's cage so that he could see it, and demanded its face value in cash. The teller told her that she must first endorse the check, and turn it over to him before he could remit payment. She refused, saying, "Here is check. You give me money first, then I give you check." The teller repeated his instructions, emphasizing the "endorse" meant that, since the check was made out to her husband, she had identify herself as payee by signing her name on the back before the bank could act. Helga held her ground: "Not my check. Not my money. My husband's money. You give me his money, and I give you his check." They repeated that impasse several times with no progress except that the teller, assuming Helga could not understand his English, began shouting his explanations. She stomped out, saying she was going to the bank across the street.

She encountered the same problem at the second bank. However, the teller there, after cycling through the dialogue twice, reached across the counter, grasped in each hand one of Helga's blonde braids, and banged her head smartly against his grill, saying, "Sign first, then money." Helga meekly signed, accepted the cash and walked out, only to encounter on the porch the first teller: "See, Helga," he said, "I was right, wasn't I?" Helga snorted, "No, you only shout at me. Here they help me understand."

My aspirations for this evening were simply to help you understand. I hope I was nearly as successful as Helga Johannsen's bank teller.

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[1] Morison, E. Men, Machines, and Modern Times. MIT Press, Cambridge, MA. 1966.
[2] U.S. Document 1411, 41st Congress, 2d Session, 1869-70, Vol. One, Part One.
[3] Cf. Green, C. McL. Eli Whitney and the Birth of American Technology. Little, Brown, and Company, Boston, 1956.
[4] E.g. Woodbury, R.S. of MIT, article in the journal Technology and Culture, Summer, 1960, and the work of Merritt Roe Smith quoted by Baida, P. "Eli Whitney's Other Talent." American Heritage. May/June 1987, Vol. 38, Issue 4.
[5] Taylor, F.W. The Principles of Scientific Management. Norton Library Edition, New York, 1967
[6] Custer's victory at the Rockfish Gap was eclipsed by his defeat at Little Big Horn, Henry rifles notwithstanding.