Inevitable Sword of Heat

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History has shown that strategy, tactics, concepts, and even politics, as well as world-power positions, all eventually adjust to technology.[1]

— Benjamin Delahauf Foulois

I HAD FOUND THE death ray. In 1966 I was just 12 years old, wandering among displays at an engineering exhibition in the field house of the University of South Carolina. Having just read H.G. Wells' "*War of the Worlds,"* I was much attuned to heat rays, at least from a fantastical point of view. Wells' "ghost of a beam of light" that wreaked havoc on the poor earthlings of Woking, England, prompted many young readers to ask could such a weapon be built. Was Wells' "sword of heat" really possible?

The answer was yes. Death rays were fact, and in 1966, I could almost reach out and touch one, or at least its humble ancestor. In the University of South Carolina field house, I was watching as the laser project's author/builder, much older than I was, stood there in a white shirt and a narrow black tie, bantering as he prepared the laser device to fire. To *fire*! That sounded so cool . . . and ominous. Firing would take a while, he explained, because of some cosmic combination of a power source and something-or-another about a "capacitor" (whatever that was). A faint humming emanated from a black transformer and the rather small laser assembly (containing a ruby rod and flash tube) housed in an aluminum sheet metal box mounted on a plain piece of plywood.

As the firing sequence progressed and the banter continued, I found the courage to ask the man how he came to possess a ruby rod. I was supremely proud to know about this fundamental bit of laser technology by virtue of a U.S. Air Force recruiting commercial that ran early on Saturday mornings. It was my first real scientific exchange on the topic. He looked down at me and spoke gravely. It was "on loan from General Electric," he said. I thought, "Gosh! General Electric has ruby rods to loan out! What if the Russians got one?"

The humming continued. I leaned closer. A nearby adult put a hand on my chest and in a gentle, avuncular way, pushed me back slightly. However, I was not going to miss this. I waited to see a dazzling stream of photons

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PHOTO: Original caption: Celestial Toys for Young Space Cadets. New York: Dressed in a space suit and clasping his toy "ray gun," this youthful spaceman prepares to ride his erector set rocket into the outer regions of space in quest of high adventure. 21 October 1952 (Copyright Bettmann/Corbis / AP Images)

A commemorative sculpture of Dr. Charles Hard Townes in Greenville, SC. Doctor Townes is said to have received his inspiration for the laser while sitting in this creek-side park in 1951. (Courtesy, HMdb.org; photo by Brian Scott, 1 June 2008)

in "lock-step" coherence rip into its target.[2] On this day in 1966, the target was a balloon across the room.

Suddenly, there was a "zap" or actually, a sound more like the "snap" of a cap pistol being fired, followed immediately by the unmistakable pop of the balloon. Success. Target destroyed! However, there was no blinding flash of light. No wave of heat.

Looking at the remnants of the balloon, I wondered what the future held for the device. This had been a rather meager display. A new crowd edged in, pushing me away. Then, someone joked to the laser man, "Hey fella . . . Have you ever tried lighting a match with this thing?"

That encounter was just over 50 years ago, but as I write this, the future that H.G. Wells contemplated in the 19th century is here. In the 21st century, aerospace forces stand on the cusp of immense changes due to rapidly advancing laser technology. An airman's ability to survive and operate, including a combatant commander's options, may now be in doubt in an environment made much more lethal because of lasers. Yes, after somewhat of a hiatus, death rays are back, and they are very potent.

Now powered up and packing a photon punch, lasers are no longer just range finders and guidance systems components. They can affect matter over great ranges, and the United States and other nations are pursuing laser weapons with future battlefields in mind. Certainly, as with most technological advances, old comfortable paradigms need scrutiny and reevaluation. We may have to cast them aside completely. Moreover, the very nature of the laser—light challenges an aircrew as never before. To prepare for future engagements and to survive them, a robust dialogue within the aerospace community is essential.

The March of Laser Technology

The year 2010 in particular was a great year for laser weapons. Just how great? The open-source world brims with myriad "firsts" and breakthroughs heralding great change. Here are some of the more recent, perhaps ominous ones:

- Breaking the 100 kW threshold with a solid state laser.[3]
- The Army testing green lasers for defense.[4]
- The U.S. Navy shooting down unmanned aerial vehicles.[5]
- The Army planning to test lasers in shooting down incoming rockets and mortars.[6]

Intriguing terms jump out: "missiles," "mortars," and "unmanned aerial vehicles." These objects loom large as targets in most of the events. Even more disquieting to the aviator is the fact that for the most part, they all entail shooting things down . . . out of the air. The implications for airpower employment are self-evident. The air warfare environment that aircrews find somewhat comfortable today is going to get much more lethal tomorrow. (The reader will note the list above is limited to U.S. efforts. However, the United States is not alone in these pursuits.)

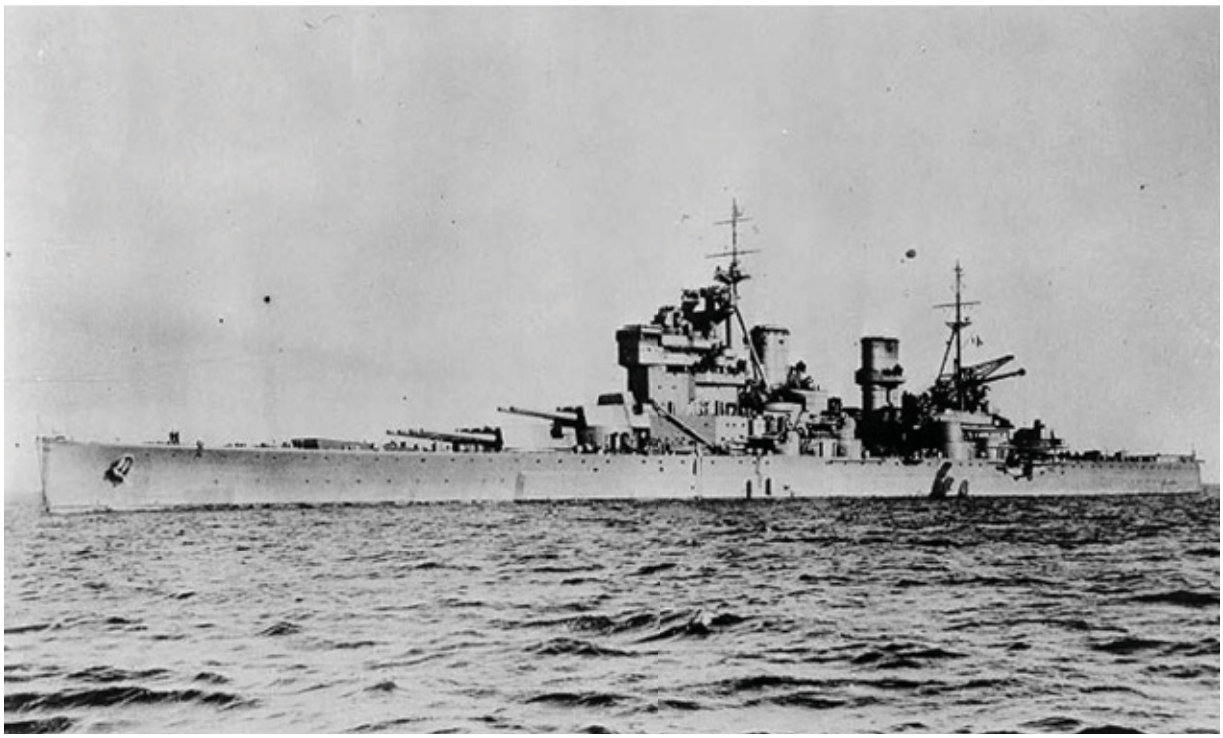
Who Is Doing What?

Hearing ominous things about lasers, most readers will first think about the Chinese. And why not? Search around the open sources and there is plenty to read. Indeed, China maintains interest in a "larger class of weapons" or what it calls *xin gainian wuqi* ("new concept weapons").[7] Within that category are "high power lasers, high power microwaves, rail guns, coil guns, [and] particle beam weapons," according to a 1999 report.[8] The 2005 Annual Report to Congress on China's military prowess asserted that China researched "ground-based laser ASAT [anti-satellite] weapons" and recorded that the Defense Intelligence Agency believed "Beijing eventually could develop a laser weapon capable of damaging or destroying satellites."[9] In 2006, a hullabaloo arose over the supposed blinding of a U.S. space satellite by a Chinese laser.[10] The event was later "clarified" when the U.S. National Reconnaissance Office confirmed that a Chinese laser "illuminated" a U.S. satellite that year.[11] In 2007, reports suggested China "continues a trend of annual [military] budget increases that significantly exceed growth of the overall economy."[12] This last development, more than anything, evinces China's laser ambitions. It is reasonable to think of China as sedulous in its pursuit of laser weaponry.

Given the American military's great reliance on space systems, it is safe to assume Russia is looking for ways to offset U.S. dominance in some fashion or another. Always wary of America and its allies' theater missile defense efforts, it is only natural for Russia to seek parity, somewhere.[13] Actually, the United States and Canada have already engaged Russia in a type of laser warfare. Aircrews of both nations suffered eye damage in a rather infamous sea surveillance incident off the coast of Alaska in 1996.[14]

Paradigm Busters?

The auguries seem grim. Lasers are moving toward lethality. Other nations are striving to imbue their laser systems with high wattage and mobility. Is the aviation community taking all of this into consideration? Is it looking far enough ahead to see the ramifications and implications of these developments? Are our scenarios for laser weapons realistic enough?



(Courtesy U.S. Naval History and Heritage Command)

The HMS *Prince of Wales*, pictured, along with 26,500-ton HMS Repulse, were destroyed by Japanese aircraft while returning to Singapore, 10 December 1941, in the first sinking of heavy vessels on the high seas by aircraft.

There is precedent for anxiety; history is replete with examples of ignored or little-understood novel technologies destroying old ways of doing business. Nineteen years before the first laser shot, as World War II ramped up in the Pacific, on 10 December 1941, two British capital ships steamed toward Singapore to engage a Japanese flotilla threatening British interests there. One of the ships, the HMS *Prince of Wales,* was a relatively new battleship; the other ship, the HMS *Repulse,* was a still-formidable, World War I-era battle cruiser. Aware of the convoy and its mission, Japan elected to attack it with airpower, launching 84 torpedo planes to strike the convoy. The outcome of the attack was lopsided. The *Prince of Wales* and the *Repulse* sank in just under three hours within a few minutes of each other and in sight of each other.[15] His Majesty's Navy should have seen the disaster coming. In 1941, the world was aware of new aviation technologies and abilities and that aircraft could sink a ship. Pearl Harbor had just been attacked 72 hours earlier. Nevertheless, a British Navy commander clung to a certain mental model, elected not to change his fleet defense all that much, and the United Kingdom lost two warships and close to 1,000 lives.[16]

This was the first sinking of heavy vessels on the high seas by aircraft.[17] The Japanese lost only three aircraft. Upon hearing the news, Winston Churchill later recalled, "In all the war, I never received a more direct shock."[18] The 1941 attack compels us to ask, "Is the past prologue?" The answer: The airpower community's new science of laser capabilities *could* lead to an aerial version of the sinking of the *Repulse* and the *Prince of Wales*. This naval episode illustrates the penalty of failing to grasp the import of a new technology. Aircraft capabilities have long been the "edge" of "cutting edge" technologies, delivering many surprises to ground and ocean-going forces. However, now, airpower is in danger of being on the receiving end of the cut, so to speak. Moreover, our air brethren (who regard themselves as innovative thinkers and doers) do not always see far enough ahead to prefigure the full ramifications of new technologies.

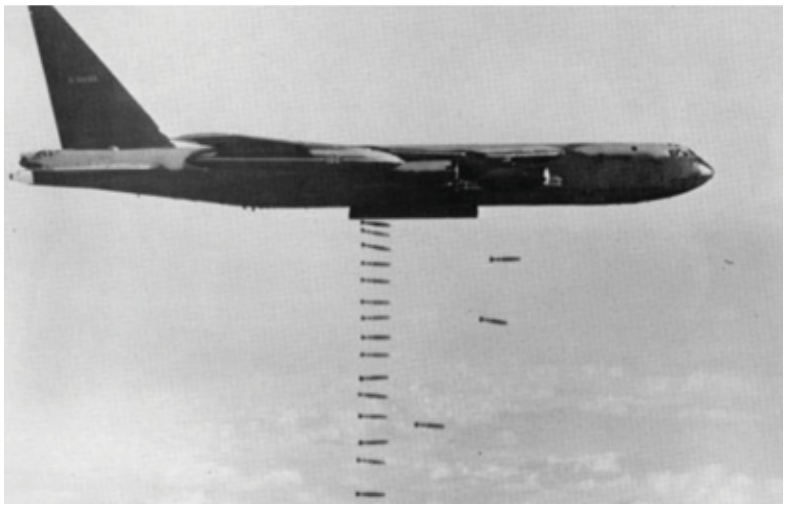
As to that last point, a few timeline examples follow:

● **Beyond visual range**. Many believed air-to-air missile technologies would obviate the close-in air combat of World War II. So pervasive was this idea that internal guns were disregarded in new jet aircraft; the Vietnam experience showed the applicability of the old-fashioned dogfight and eventually the F-4E, unlike its F-4 predecessors, were equipped with a gatling gun.[19]

● **Missile defense.** The belief that the Soviets could not build a high-altitude surface-to-air-missile led to the false assumption that flying at super high altitudes provided safety. In 1960, Francis Gary Powers was shot down while flying over the Soviet Union at an altitude of 70,000 feet by—you guessed it—a high altitude surface-to-air-missile.[20]

● **Jet engines.** Aircraft speed and performance dramatically increased, yet pilots operated World War II-style. Fighters attacked low and fast and flew through intense concentrations of antiaircraft fire.[21] Bombers still flew in long predictable "trail" formations reminiscent of the Schweinfurt raids. Vietnam then demonstrated the need to reevaluate tactics and procedures.[22]

The preceding examples are by no means all-inclusive. Nor do I mean them to be a stinging indictment of any one particular aviation community. However, the examples *do* illustrate that the aviation community thinks it gets it right, but, sometimes it doesn't, or at least not completely right. Studying the past and looking to the future might keep catastrophic laser encounters off the we-should-have-seen-that-coming list.



A B-52D delivering gravity bombs in Vietnam. Long formations of these bombers created predictable ingress paths for air defense networks that surrounded Hanoi. (U.S. Air Force Photo)

Perhaps lasers will be to airpower, as airplanes were to naval power. For decades, air defenses and associated technologies dictated where aircrews operated. Aircraft operated in a more or less "saw tooth" manner; during World War II, flying high, and then low during the Cold War (to penetrate Soviet defense); then high again (e.g., Operation Linebacker); and high yet again, using stealth technology and precision weapons. Since Operation Desert Storm, air operations have pretty much stayed in the higher altitudes. It is a nice place to be: out of the range of low altitude threats, while negating detection and SAM threats vis-à-vis exotic, stealthy materials. Not bad. Until now.

You Cannot Outrun the Photon

The very nature of the laser weapon is what makes operating against it so challenging. Stealth helps a pilot evade detection, but if perchance, he is visually acquired, stealth cannot help his aircraft outrun a beam of light. Furthermore, the laser is a line-of-sight weapon. Once the target is in the weapon's sight, to fire the weapon is to kill the target (assuming of course the weapon is perfectly bore sighted). A chilling reality it is: no leading the target (good old fashioned "Kentucky windage") is necessary, and lock-on might be a thing of the past. The mental image of F-22s flying in formation and disintegrating in rapid succession as an invisible infrared laser flicks from one *Raptor* to another, *a la* an H.G. Wells scenario, is an uncomfortable image, but definitely not an impossible or improbable one. Indeed, the laser takes us into *terra incognita.*

While all the aforementioned are true, it is important to note that the laser is not the "sword of heat" described by H.G. Wells. Sorry, Mr. Wells; you had a great imagination, but on this point, you were wrong. The laser *creates heat,* but for the laser to do damage, it must remain on the target for a certain length of time. Most readers understand this concept by virtue of various texts and arguments surrounding the airborne laser (ABL). For this weapon to work, it must acquire its target (an enemy rocket, for example), range it, adjust for the atmosphere, fire the high-level laser system, and maintain its beam on the target's skin, or, *"dwell"* on the target. The dwell must be long enough for something to melt, burn, or explode.[23] Laser engagements against aircraft follow the same process.

Knowing the above, aircrews must consider how to—

- Survive the engagement.
- Evade the engagement.
- Continue the engagement.

Surviving the engagement. To survive at altitude, first think "protection," and protection might mean ablative material. For ablative material, think "heat shield." The function of ablative material is simple. As the surface heats up, the material burns off, taking energy with it, and thus keeping the protected mass cool. It works. Anyone looking at the reentry end of the Apollo space capsule in the foyer of the National Air and Space Museum can see how the heat shield slaked off in bits and pieces as it plummeted through the atmosphere.

Ablative material, however, is likely to be heavy and perhaps not stealthy. Moreover, anyone familiar with lift equations knows that as weight is added to an aircraft, lift must increase, and this entails more energy, which means more fuel. Soon, we find ourselves in the realm of rather large, unwieldy airplanes encased in ceramics. This is a *possible* solution, but not a likely one, without some breakthrough in exotic materials.

Evading the engagement. What about evasive action and maneuvering (jink)? Is this an answer? Remember that "threshold" breakthrough that occurred just shy of the laser's 50th birthday, the breaking of the 100kW mark? It should have made the aviation community take note. Within the laser development community (notably Northrop Grumman), crossing the 100 kW threshold meant weapons-grade high-energy lasers were in the offing. Simply put, a laser is energy, and the more energy that goes into *making* the beam, the more energy *in* the beam itself. However, even lesser power ranges—in the range of 25 kW or 50 kW—combined with good beam quality yield "many militarily useful effects."[24] And if the laser beam is pulsed (causing several mini-hits on the target in a short timeframe) the dwell time problem is reduced. To the aviator, the fastest jink may just not be fast enough.

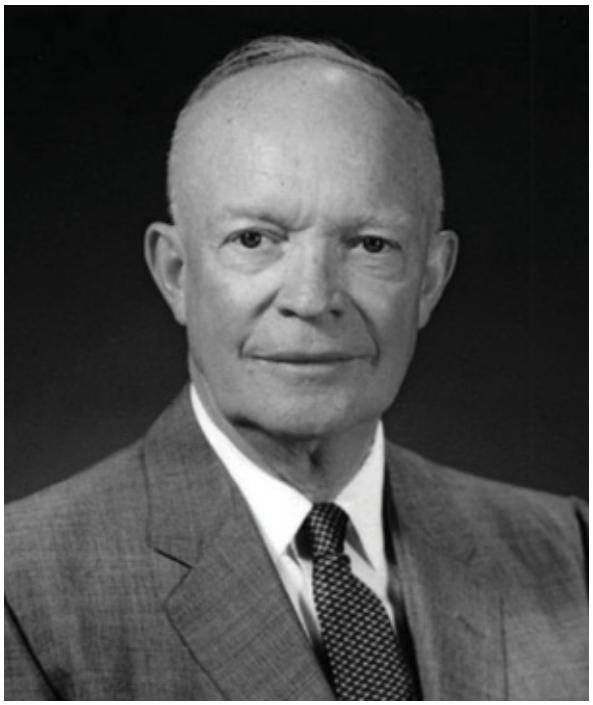
Perhaps, with luck, one can attack on the proverbial dark and stormy night. I am not being flippant. Such an attack would be a realistic approach to solving the problem based on simple physics. Water vapor and other particulate matter seem to confound

the laser weapon's lethality. Indeed, the U.S. Navy is contemplating this problem now as it is "learning to cope with the extra difficulties of running a finely tuned electro-optical device in the harsh maritime conditions near the sea surface, where water vapor in the air tends to scatter and attenuate directed-energy beams."[25] This being the case, the U.S. Air Force's various claims that it is an all-weather force become relevant to fighting against laser weapons.[26] The confounding effect of foul weather is not a bad defense, if the weather cooperates. However, we cannot count on bad weather. We cannot control the weather. However, we can control altitude.

As noted earlier, over the decades, airpower used different altitudes (high, low, or a combination thereof). Are aviators heading back down into the weeds again? Maybe so. If so, we must remember that low-level flights, while exciting, have drawbacks: a pilot can only fly so low before the risks outweighs the advantages of doing so, and the lethality of some intense systems—the ZSU 23, for example—weigh heavily (lots and lots of projectiles fill the airspace). Low altitude is tough on airframes, too. Even so, nothing works so well as the tried and true method of putting terrain features between the pilot and the threat looking for him. Perhaps it is time to dive back into the low altitude environment again. And in doing so, in the words of T.S. Eliot,

We shall not cease from exploration.
And the end of all of our exploring
Will be to arrive back where we started.[27]

Of course, difficult issues arise. Is it wise to put a multimillion-dollar aircraft in a low-level environment? Is this the way to counter susceptibility to laser weapons? Moreover, if the aircraft is too vulnerable, the dreaded acquisition issues surface again.



President Dwight D. Eisenhower questioned aircraft acquisition programs given the advent of new Soviet capabilities and defenses during his tenure. (U.S. Federal Government)

These issues are not new; all neophyte systems teeter on the edge of an abyss when we weigh their effectiveness against the entities that negate them. President Eisenhower wrestled with this conundrum as he considered the planned supersonic bomber, the B-70 *Valkyrie*, although "convinced that the age of aircraft for actual use over enemy territory is fast coming to a close."[28] In his constant weighing of defense needs against budgets, he reflected on weapon systems made passé by technological advances and concluded, "We were talking about bows and arrows at the time of gunpowder when we spoke of bombers in the missile age."[29]

This argument will likely surface again, if it has not already. Replace the word "missile" with "laser" in President Eisenhower's quote above, and the implications are clear.

Continuing the engagement. Despite the potential awesomeness of the laser weapon, and our visions of hapless F-22 formations, not all the news is bad. It is not going to be all *that* easy for the bad guys equipped with antiaircraft lasers (AALs), either. To successfully engage the target, they must first acquire it. To do that, they must overcome the target's stealth properties with some type of acquisition capability, and the AAL must have ranging equipment. As is the case with the USAF's airborne laser, the Boeing YAL-1, a laser separate from the high-energy killing beam does the ranging.[30]

Thus, the enemy uses a laser to *find* and *range* a target, and the enemy AAL battery gives its own position away. (Lasers, like tracers, work both ways.) For friendly forces, it is back to the old way of doing business. We fix the AAL battery's position through its emissions and release guided ordnance to destroy it.

Moreover, despite strides in solid-state laser

A B-52D shown conducting a launch of an ADM 20 Quail decoy. (U.S. Air Force)

weapons (which also allow a greater rate of fire), an alternative might be to overwhelm the AAL. Now we move into the realm of Sun Tzu's famous edict: "All warfare is based on deception."[31] Here, the deception translates to decoys.

The time may be right for a boom in the deception business that causes us to look at new ways to bamboozle our laser-equipped enemies with highly sophisticated trickery. The concept is neither radical nor novel, and the Air Force has some experience doing this sort of thing. The ADM 20 Quail was supposed to create a radar image much like the B-52 that carried it and launched it.[32]

The concept is simple: create a target-rich environment via a multitude of decoys with real aircraft embedded in the fleet. Assume that a laser device bent on destroying incoming aircraft needs some type of regeneration cycle, or time to "reload." This is especially true of the chemical laser.[33] If this is the case, as the AAL engages, a plethora of targets will render it useless if it cannot discern real aircraft from decoys. The AAL expends its power sources in futile attempts to destroy the real penetrator, wherever it may be in that myriad of radar contacts that clutter the scope. Is it time to dust off this decoy technology? Perhaps these "dec tech" systems need a new look.

Furthermore, consider an AAL's signature. Laser weaponry is still pretty bulky stuff, so the AAL is not yet all that mobile. True enough, some strides have been made in this area, at least in the United States.[34] But their lack of mobility notwithstanding, whether solid state or chemical, when lasers fire, they create quite a signature. Both the Measurement and Signature Intelligence and Technology Intelligence communities now become important partners in detecting and countering an adversary's capabilities.

Joining the "Urgent Crowd"

The ponderings in this article come from one ex-aviator; with luck, others from all services will weigh in with opinions, ideas, and counter positions. This is appropriate. Not long ago in *Air and Space Power Journal* an article stated it hoped to impart readers "with a sense of urgency" regarding directed energy weapons.[35] That has happened. While not a physicist, this ex-aviator tosses his hat in with that "urgent crowd." Yes, technology fascinates aviators. Now comes the concomitant brainstorming about how to deal with the awesome laser technology by creating realistic scenarios. We must keep the dialogue and thinking in motion. With luck, others will start thinking through these issues.

Last year Joseph Cirincone, president of the

An ADM 20 Quail decoy with Strategic Air Command markings. (U.S. Air Force)

Ploughshares Fund, was pleased that ABL funding was cancelled, going so far as to deride it as a "Flying White Elephant" that would never work.[36] This derision is unwarranted. His and similar statements bring to mind what John Haldane, British Secretary of State for War, said in 1910: "We do not consider that aeroplanes will be of any possible use for war purposes."[37]

Of course, 30 years later, almost a whole fleet was decimated at anchor in Pearl Harbor, and Haldane's nation, Great Britain, lost the HMS *Repulse* and HMS *Prince of Wales* three days after that.

Conclusion

Laser weapon systems are extraordinarily lethal because they can operate at the speed of light; a laser is light itself. Laser weapons therefore present huge challenges. Perhaps air fleets facing laser weapons can survive, but it will take forethought and candid analysis, and one hopes not a catastrophic incident, to figure out how.

History shows that the aviation community can be slow to grasp the import of such technological challenges and adapt to them. Dealing with the new lethal laser environment—where the hit is instantaneous with the trigger pull—will require bold acceptance of ramifications affecting old paradigms and new acquisitions. These weapons will be fielded, too. Note that H.G. Wells certainly did get one thing right with his concept of the "inevitable sword of heat" … Note the word *inevitable*.***MR***

NOTES

1. Benjamin Delahauf Foulois and Carroll V. Glines, *From the Wright Brothers to the Astronauts* (*Flight, Its First Seventy-Five Years)* (North Stratford, NH: Ayer Company Publishers, 1979), 286.

2. Many sources on physics will describe "coherence" in many different ways, but in regard to laser light and envisioned by Townes means photons are in a lock-step marching sequence as opposed to random and varied wavelengths found in, for example, an incandescent light bulb.

3. William Matthews, "Visible Progress for Laser Weapons: Yet Energy-Beam Munitions Remain Years Away," *Defense News*, March 2010.

4. "Army Testing Green Laser Kits in Afghanistan," *Defense Technology News*, Army News Service, 7 June.

5. "Navy Laser Destroys Unmanned Aerial Vehicle in a Maritime Environment," from Naval Sea Systems Command Public Affairs, Official U.S. Navy Web Site, story number: NNS100529-09, 29 May 2010.

6. Dan Vergano, "'Star Wars' meets reality? Military testing laser weapons," *USA Today,* 14 May 2010.

7. Mark A. Stokes, "China's Strategic Modernization: Implications for the United States," U.S. Army Strategic Studies Institute, September 1999.

8. Jon E. Dougherty, "China advancing laser weapons program—Technology equals or surpasses U.S. capability," 22 November 1999; 2010 WorldNetDaily.com.

9. "Annual Report to Congress: The Military Power of the People's Republic of China.

10. Andrea Shalal-Esa, "China Jamming Test Sparks U.S. Satellite Concerns," Reuters, 5 October 2006.

11. "Chinese Anti-Satellite [ASAT] Capabilities and ABM Capability," GlobalSecurity.org, Space <http://www.globalsecurity.org/space/world/china/asat.htm>.

12. "Annual Report to Congress: The Military Power of the People's Republic of China 2007," 25.

13. "Russia's space defenses in shambles—experts," RIA Novosti (The Russian News & Information Agency) Moscow, 13 May 2010.

14. See [H.A.S.C. No. 106–11] "Protection Equipment and Countermeasure Devices," Hearing Before the Military Procurement Subcommittee of the Committee on Armed Services House of Representatives, 106th Congress, First Session Hearing Held: 11 February 1999. This record mentions the *Kapitan Man*, the Russian vessel that purportedly lazed Lieutenant Jack Daly, U.S. Navy, and Captain Patrick Barnes of the Canadian Air Force, rendering "permanent eye damage."

15. *The War at Sea—the British Navy in World War II*, ed. John Winton, introduction by Earl Mountbatten (New York: Morrow, 1968), provides a forensic eyewitness account of the demise of the HMS *Repulse* and the HMS *Prince of Wales*, 164-71.

16. Bernard C. Nalty, *War in the Pacific* (Norman: University of Oklahoma Press, 1999), 67.

17. *"HMS Prince of Wales (Battleship, 1941-1941)," Naval History & Heritage Command, SHIPS of the British Navy*—selected images, <http://www.history.navy.mil/photos/sh-fornv/uk/uksh-p/pow12.htm>.

18. Sir Winston Churchill, *The Second World War, Volume 3: The Grand Alliance* (New York: Mariner Books, 1986), 551.

19. Factsheet: "McDonnell Douglas F-4E," National Museum of the U.S. Air Force, <http://www.nationalmuseum.af.mil/factsheets/factsheet_print.asp?fsID=2277&page=1>.

20. "CIA, NRO, and Air Force Celebrate the U-2: A Revolution in Intelligence," Central Intelligence Agency Website, 28 September 1998, <https://www.cia.gov/news-information/press-releases-statements/press-release-archive-1998/pr092898.html>.

21. "Air War Vietnam" by Arno Press Staff, Inc. Drew Middleton (intro.) (New York: Arno Press, 1978). Excellent analysis in Part II, by COL John A. Doglione, COL Donald T. Hogg, et al., that explains how in the sample year of 1965 most fighter aircraft were brought down by antiaircraft fire as opposed to MiGs, 224.

22. Marshall L. Michel, III, *The 11 Days of Christmas: America's Last Vietnam Battle* (San Francisco: Encounter Books, 2002), 162.

23. "Reusable glass target board to test and evaluate High-Energy Laser Weapons," Frontier India, 18 August 2010; Category: Latest, N & S America.

24. Photo Release—"Northrop Grumman Scales New Heights in Electric Laser Power, Achieves 100 Kilowatts from a Solid-State Laser," <http://www.irconnect.com/noc/press/pages/news_releases.html?d=161575>.

25. "Beam Weapons Make Headway," DarkGovernment, 18 May 2010, <http://www.darkgovernment.com/news/beam-weapons-make-headway/>.

26. Note: "all weather" is not a USAF doctrinal reference, but instead shows up in various aircraft fact sheets and capability statements.

27. T.S. Eliot, *Little Gidding*, British (U.S.-born) critic, dramatist & poet (1888-1965).

28. "Memorandum of conference with the President, 18 November 1959"—20 January 1960, Augusta (declassified 1/18/81), courtesy Dwight D. Eisenhower Presidential Library, 7.

29. Ibid., 8.

30. The Boeing YAL-1 Airborne Laser (ABL) weapons system has three laser systems: a Track Illuminator Laser for illuminating the target and adjusting the parameters of the laser weapon's optical system; a Beacon Illuminator Laser for reducing atmospheric aberration; and the six-module High-Energy Laser weapon system.

31. Samuel B. Griffith, *The Art of War by Sun Tzu* (Oxford University Press, 1963), 66.

32. Factsheet: "McDonnell ADM-20 Quail," National Museum of the U.S. Air Force, <http://www.nationalmuseum.af.mil/factsheets/factsheet.asp?id=384>. As a member of Strategic Air Command, I gained experience with the system in the waning days of the Cold War

33. Noah Shachtman, "Attack at the Speed of Light," *Popular Science*, posted 05.01.2006 at 1:00 am, <http://www.popsci.com/military-aviation-space/article/2006-05/attack-speed-light?page=>.

34. "Boeing *Laser* Demonstrator Program Accepts Oshkosh *Military* Truck—Enters Fabrication Phase," *Boeing Media*, 6 January 2010.

35. MG David Scott, USAF, and COL David Robie, USAF, "Directed Energy—A Look to the Future," Senior Leader Perspectives, *Air & Space Power Journal* (1 December 2009).

36. Ploughshares Fund is a public grant-making foundation focused on nuclear weapons policy and conflict resolution

37. See "Aviation Quotes" <http://www.456fis.org/THE_HISTORY_OF_FLIGHT_-_AVIATION_QUOTES.htm>.