The Coming Close Air Support Fly-Off

Lessons from AIMVAL–ACEVAL

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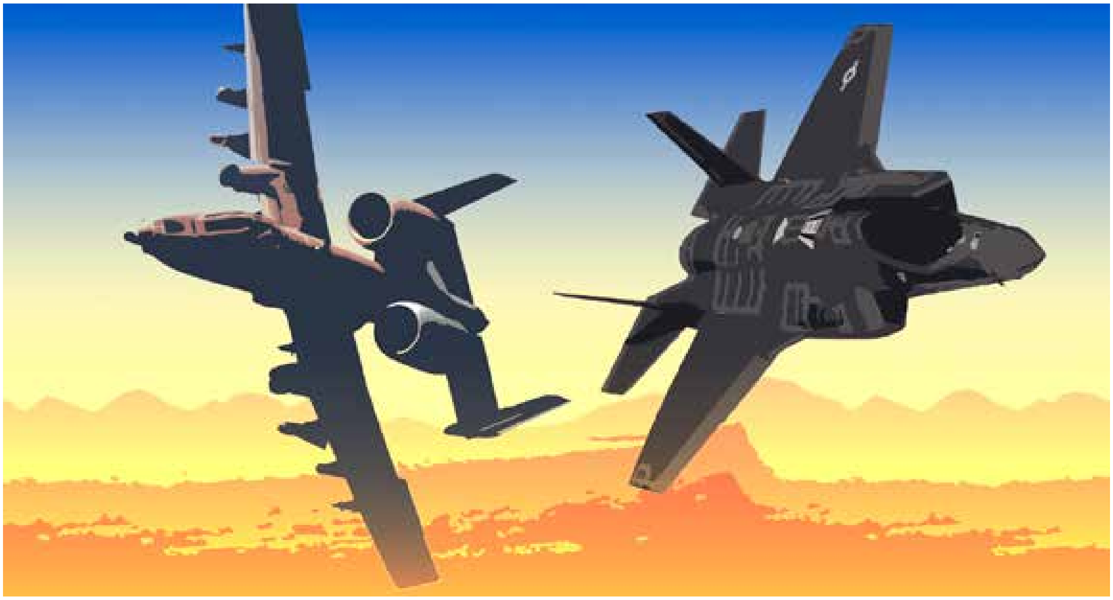

At the behest of Congress, the Pentagon is poised to conduct a fly-off to determine the future viability of the Air Force's close air support (CAS) platforms. For the past several years, the Air Force has tried to retire its fleet of A-10s, suggesting that its other platforms, including newly-arriving F-35s, could assume the CAS mission from the venerable but aging Warthog. These more modern platforms armed with an array of high-tech weapons, Air Force officials often explained, could better achieve the desired CAS effects across any battlespace, including regions where enemy defenses might otherwise imperil the low, slow A-10.[1] The service's position met significant opposition, however, extending from the blogosphere to congressional chambers. Advocates for the A-10 countered that the relatively simple, battle-hardened Warthog brings irreplaceable capability and weapons effects to the battlefield, and at a fraction of the procurement and operating costs of the service-favored F-35.[2] To prove their point, several A-10 proponents repeatedly called for a fly-off between the two platforms, but in August 2015 Air Force Chief of Staff Gen Mark Welsh quipped that such a test "would be a silly exercise."[3] Then in the summer of 2016, Rep. Martha McSally (R-AZ), a former A-10 combat pilot, introduced legislation requiring a head-to-head test of the two platforms during a portion of the F-35A initial operational test and evaluation; the fly-off would have to be completed before Congress authorized any additional changes to the A-10 force structure.[4] In an opinion piece published in *The Air Force Times*, McSally outlined the test's objectives, "The testing must demonstrate how the two aircraft can perform missions in realistic combat settings, such as when pilots are required to visually identify enemy and friendly forces in close proximity, both during the day and at night."[5]

While recent reports indicate that the new Air Force Chief of Staff, Gen David L. Goldfein, has elected to push the A-10 retirement out to 2021, the rancorous A-10 versus F-35 debate is likely to persist, and the mandated CAS fly-off is still slated to occur in early 2018.[6] It is, therefore, still worth evaluating the potential merits and pitfalls of the forthcoming F-35/A-10 matchup, which will be conducted under the supervision of the Pentagon's Director of Operational Test and Evaluation (DOT&E). For that, I suggest we first examine the notion of military testing and then turn to a potentially informative historical example of two congressionally-mandated tests conducted 40 years ago—the Air Intercept Missile Evaluation and the Air Combat Evaluation (AIMVAL–ACEVAL).

The Social Construction of Military Testing

From an early age, we are taught that to gain new knowledge we must construct hypotheses, design experiments to test those hypotheses, and then evaluate the results to prove or disprove our hypotheses. The process is known as the *scientific method,* and it brought the world out of the Dark Ages. While the triumph of experimentalism in the mid-seventeenth century and the corresponding scientific revolution has long been assumed to have been a smooth transition—a self-evident and predestined transformation in the development of human knowledge—the historical record suggests otherwise. As Steven Shapin and Simon Schaffer observed, the rise of experimentalism generated existential questions concerning "the nature of knowledge, the nature of the polity, and the nature of the relationship between them." Robert Boyle and the experimentalists prevailed, but "[Thomas] Hobbes was right. . . . Knowledge, as much as the state, is the product of human actions."[7] Shapin and Schaffer's conclusions are not unique. Thomas S. Kuhn, Robert K. Merton, Bruno Latour, and David Bloor have all demonstrated that "discoveries entail more than empirical findings"—they are products of human environments and human interactions.[8] Consequently, despite its aura of objectivity and the search for *truth*, "scientific activity is not 'about nature,' it is," as Latour and Steve Woolgar explain, rather "a fierce fight to *construct* reality" (emphasis in original).[9]

Hence, even if empirical data assume the form of impartial charts, plots, tables, and numbers, it is critical to recognize that the data still reflect the idiosyncrasies of the unique social environment in which they were mustered. The statistician Joel Best reminds us that gathering and interpreting data requires people to make choices; for example, what should and should not be included in the dataset.[10] These dataset choices are defined by individuals' specific understanding of the problem and their hypotheses that identify important contributing factors. While groups can sometimes agree on a common definition of the problem and associated hypotheses, more often they cannot. Conflicting interpretations inevitably yield different datasets, which consequently generate new sets of statistical results. While some may impute malfeasance on those who generate disagreeable data, often the data discrepancy simply results from the different circumstances and contexts in which the data were gathered.[11] Thus, despite the tendency to regard numbers and statistics as unalterable representations of the truth, they are better understood as products of "people's choices and compromises, which inevitably shape, limit, and distort the outcome."[12] Borrowing a term from Trevor J. Pinch and Wiebe E. Bijker's application of social constructivism to technology, data inherently possess "interpretive flexibility."[13]

But if all data are socially constructed, how then can we overcome the associated relativism to discern the *truth*? For Best, the answer is a scientific process that facilitates the cumulative generation of knowledge.[14] Within this model, doubts that may accompany individual test results are gradually removed when multiple researchers exploring similar phenomena, each using a variety of techniques, methods, and data, converge on similar outcomes and understandings. Modern scientific and engineering practice is configured to encourage just such investigation, replication, and corresponding dialogue. Edward Constant's story of turbojet engine development is but one illustration of how "communities of technological practitioners" can help separate spurious data from more promising representations of reality.[15] Walter G. Vincenti offers a complementary example in his history of early aeronautics development.[16]

Unfortunately, structural impediments often limit the military's ability to foster a similar "marketplace of ideas." Unlike the commercial or academic sector, the military cannot rely on Constant's robust yet independent communities of technological practitioners to facilitate the cumulative knowledge generation process. While the Pentagon's DOT&E office represents a non-service-specific organization established to manage military testing, it is only a single organization, and the military's tests still necessarily rely on service-specific personnel, hardware, and training; these resources are not available to other independent agencies outside the military structure that might want to investigate alternative hypotheses. (Of course, the enemy represents an excellent independent authority, but fortunately for humankind's sake, empirical testing opportunities against enemy forces are typically rare.) Additionally, the results of the military's experiments are often cloaked under the veil of national security, restricting independent and nonmilitary researchers' access to the data (military researchers, too, can be restricted by multiple layers of bureaucracy). Finally, military tests can be costly, and they are often tied to specific schedule-driven programmatic decisions, which collectively can conspire to limit the tests' flexibility and their ability to investigate anomalies.[17]

Despite these structural impediments, the military still maintains a robust testing enterprise, which includes its array of recurring exercises, war games, and weapons system test programs. Since Robert McNamara's term as US defense secretary, military leaders have relied on the ever-increasing amounts of numerical data and statistically-informed prognoses produced by these tests to help them navigate the technical and doctrinal requirements of the next conflict.[18] However, as Best inferred, the accumulated data used to guide defense decision making and resourcing remain a product of the unique environment and organization in which they were gathered. Moreover, the interpretive flexibility inherent in the data is exacerbated by divergent, value-laden interpretations of future national defense requirements, themselves buffeted by frequently changing political circumstances and agendas. The famed British strategist Sir Basil Henry Liddell Hart captured the challenge that confronts military leaders sifting through the mounds of data: "Before a war military science seems like a real science, like astronomy, but after a war it seems more like astrology."[19]

Within this context, the military's inability to conduct independent, transparent, and appropriately flexible testing frequently invites outside skepticism, despite defense officials' repeated assurances that their tests are fair and impartial.[20] Indeed, according to the social constructivist perspective, the military's penchant for arguing about the validity of its data is misplaced; there can be no truly fair and impartial environment. However, because of the unique military environment, there is also little opportunity to engage in the robust scientific knowledge generation process that Best and others recommend. This can leave the military in an intractable position.

The history of the joint Air Force and Navy AIMVAL–ACVEVAL tests conducted in 1977 illustrates these limitations of military-generated knowledge, and the two tests foreshadow the conundrum that the Department of Defense (DOD) and the Air Force will likely face when they attempt to address divergent hypotheses about the future of CAS during the coming A-10/F-35 fly-off.

AIMVAL–ACEVAL

AIMVAL–ACEVAL emerged from competing hypotheses about the future of air combat post–Vietnam.[21] By 1975, the Air Force and the Navy had already begun aggressively modernizing their tactical fighter forces to face an increasingly-capable Soviet threat. New technologically sophisticated aircraft such as the Air Force's single-seat F-15 Eagle and the Navy's two-seat F-14 Tomcat were rolling off assembly lines.[22] The services had agreed to outfit their premiere fighters with a common medium-range, radar-guided missile—the updated solid-state AIM-7F Sparrow.[23] However, the services diverged on their requirements for their fighters' shorter-range, infrared (IR)-guided armament. The Air Force preferred a cheap, simple but effective missile for their Eagles, which they appropriately named the CLAW.[24] The Navy, on the other hand, wanted a technologically exquisite, helmet-cued, thrust-vectored, high off-boresight missile they called the Agile.[25] To "bridge the gap" between their Vietnam-era Sidewinders and their futuristic CLAWs and Agiles, the Air Force and Navy were also jointly developing a third short-range IR-guided missile, the all-aspect-capable AIM-9L Sidewinder.[26] When Congress was handed the bill for the three missiles, it balked.[27] Instead of funding the services' requests, in 1975 Congress cancelled the CLAW and Agile programs and ordered the Pentagon's director of Defense Research and Engineering (DDR&E) to conduct a test to identify the best short-range, IR-guided missile, hoping to force the two services into agreement on a common design. The congressionally-mandated test became known as AIMVAL.[28]

DDR&E, in turn, levied its own additional test requirement on the services. With the Air Force and Navy committed to procuring their advanced Eagles and Tomcats, analysts within the DOD realized that they had no data that would allow them to quantify the relative advantage of the services' newest generation of fighters. Most agreed that a single Eagle or Tomcat was more capable than a Soviet MiG-21, but nobody was sure if a single F-15 or F-14 was equivalent to two, three, or even four MiG-21s. The second test—ACEVAL—was ordered to answer this force-planning question.[29] The two tests were to be conducted sequentially by a single joint test force (JTF) operating out of Nellis AFB, Nevada. They were scheduled to commence flying the following year in 1976.

The services recognized immediately that the outcome from the AIMVAL–ACEVAL tests would significantly affect their future acquisition strategies. The first joint test director, RADM Julian Lake, was explicit in his initial communique, declaring, "[AIMVAL–ACEVAL] test analysis will be used in definition of future tactical A/C and weapon systems requirements and as such will significantly influence US TACAIR posture in [the] 80's and 90's."[30] The services also quickly realized that while they were ostensibly working together under a congressional and DDR&E mandate to define future air combat requirements, and while their Tomcats and Eagles would never be in the air at the same time against the opposing aggressor forces, the coincident matchup of Air Force and Navy aircrews with their newest equipment would inevitably invite public comparisons.[31] Consequently, some within the Air Force pressed their colleagues to "explore feasible alternatives to show [the] F-15 in the best light"; the Navy likely did the same for its F-14s.[32]

Despite the threat of service parochialism corrupting the results, test officials repeatedly emphasized during congressional testimony the "complete objectivity" of "the test plan, the test data requirements, and the manner in which the data will be handled and analyzed."[33] One strategy to tamp down service biases was to use a joint test management structure with equal Air Force and Navy representation: a Navy admiral served as the AIMVAL–ACEVAL test director; the deputy test director was an Air Force general.[34] Additionally, JTF analysts spent considerable time artfully crafting the test matrices to ensure statistically significant results within the tests' budget and scheduling constraints.[35] Most significantly, a new data collection technology—Air Combat Maneuvering Instrumentation (ACMI)—was fielded to replace pilots' sometimes hazy, often contested, memories of individual air combat outcomes.[36] One test official boasted that the only way to get a more "exact answer" from the tests would be to "fire real missiles."[37]

However, even the cornerstone of test objectivity—ACMI—still retained a level of subjectivity. Because ACMI recorded aircraft position, attitude, and weapons employment data (for up to eight aircraft), it could determine who was shooting at whom and with what type of weapon. Observers on the ground could then watch the aerial engagements unfold in real time on their computer screens, and they would notify an aircraft that it had been "destroyed" by an opponent whenever the ACMI computers predicted a kill.[38] While ACMI had the ability to account for specific aircraft vulnerabilities when calculating the probability of a successful missile kill, neither service could agree on a suitable model for their fighters: the Air Force argued that its Eagle was more survivable than the Navy's Tomcat; the Navy obviously took the reverse position. Unable to resolve the dispute, test officials reluctantly settled on a common vulnerability model for both aircraft based on an F-4E Phantom II, the now-outdated aircraft that the F-15 and F-14 were designed to replace.[39]

The decision to use ACMI levied other constraints on the test design. ACMI only functioned over an instrumented range, and at the time, Nellis's ACMI range only measured 30 miles in diameter.[40] Conscious of the limited ACMI test space, test officials announced that during both AIMVAL and ACEVAL, all friendly aircraft would be required to close to within visual range to visually identify (VID) their target before firing a missile at it.[41] While the VID requirement was commonplace during Vietnam, the Air Force and Navy investments in the long-range radars installed in their Eagles and Tomcats, as well as their joint development of the AIM-7F, signaled their hope that such restrictions would become a relic of wars past.[42] The unanticipated VID requirement also initiated another round of service one-upmanship, with the Navy suddenly announcing plans to install a television sight system (TVSU) on its AIMVAL–ACEVAL Tomcats that would extend the aircrews' VID capability. The Air Force protested that the Navy's new technological hardware would give the F-14 an unfair advantage and upset the meticulously negotiated and carefully balanced test environment, but the JTF officials ruled in favor of the Navy. The TVSU-equipped Tomcats arrived in time for the testing.[43]

Several USAF organizations registered additional concerns regarding the tests' other artificialities, including the non-combat-representative aircraft configurations and the 5,000-foot minimum test engagement altitude. Some organizations even complained that the pilots would be disadvantaged because real missiles would not be used—the aircrews couldn't look for missile smoke trails in the air to alert them to a potential threat.[44] The tests' identified dependent variables and associated scoring metrics also generated significant consternation within the services.[45] Were the aircrews supposed "to maximize the number of missile firings, . . . maximize the expected kills [while] striving for optimum [offensive] position," or, officials at Tactical Air Command (TAC) wondered, focus on "minimizing their vulnerability"?[46] Succinctly capturing the services' frustration, one Navy official wrote, "The guys who conceived and designed the whole test series clearly didn't know what they were doing."[47] Doubts also spread to Capitol Hill, where at least one Senate staffer questioned whether the test design was even capable of "really proving the thing that [the services] have to prove."[48]

Responding to these and similar criticisms shortly after the AIMVAL trials began, the joint test director, now RADM Ernest Tissot, tried to assuage the services' concerns, explaining, "The majority of the test results and relative effectiveness conclusions [*sic*] . . . should not be treated in terms of specific system absolutes."[49] Lt Gen Alton Slay, the Air Force's deputy chief of staff for research and development, took a similar approach with Congress, reminding it in his March 1977 testimony that, having "theoretically taken a big skyhook and dropped these airplanes into a 30-mile arena," the test was "a canned situation."[50]

All told, it took more than a year to stand up the test team, develop the testing protocols, spin up the aircrews, and field ACMI. AIMVAL commenced testing on 3 January 1977 and continued for more than five months. During the test, five separate short-range IR missile designs ranging from simple boresight-only missiles to extremely sensitive, high off-boresight, helmet-cued weapons, were evaluated on F-14 Tomcat and F-15 Eagle aircraft. In addition to the simulated IR concept missiles, the blue forces were also armed with simulated AIM-7F Sparrow radar-guided missiles and a 20mm gun. Opposing the F-14s and F-15s were Air Force and Navy aggressors flying F-5E aircraft armed with a modified, boresight-only version of the AIM-9L Sidewinder, a representation of a future 1985 Soviet threat. More than 1,000 trials were flown during AIMVAL, accounting for more than 2,600 total sorties.[51]

Even as AIMVAL was still underway, JTF officials declared the test a "positive influence toward the resolution of common Air Force and Navy needs" for the next short-range, IR-guided missile.[52] Of the IR missile concepts tested, however, none were judged satisfactory; all exhibited difficulty distinguishing between the fighter targets and the hot desert background. Shortly thereafter, the two services elected to shelve their advanced IR-guided missile concepts in favor of their bridge all-aspect AIM-9L. They also accelerated their work on a new high-speed, multitargetable, advanced medium-range *radar-guided* air-to-air missile—the AMRAAM.[53]

Although focused on a different question, ACEVAL supported many of AIMVAL's earlier recommendations. Executed from June to November 1977, ACEVAL used the same AIMVAL test management, much of the same Air Force and Navy equipment, and many of the same aircrews. The F-5E-equipped aggressor adversary also remained the same as during AIMVAL. Variation during the 720 ACEVAL trials, which required a total of 3,222 sorties, was primarily a function of setup parameters and force ratios.[54]

The findings from ACEVAL, according to one data analyst, could be captured in a single sentence: "As the number of fighters in an engagement increases, the exchange ratio trends toward One"; or, in other words, the larger the fight, the more likely everybody died.[55] The same analyst also noted that any attempt to view the ACEVAL results strictly in terms of competing technological hardware quickly became "incomprehensible."[56] While DDR&E's desire for a fighter force model to inform defense planning consequently went unfulfilled, some suggested that ACEVAL's "law" supported a requirement for purchasing significant *quantities* of tactical fighters.[57] Others, however, interpreted the ACEVAL results as supporting a requirement to improve the *quality* of the US tactical fighter aircraft and their air-to-air weaponry. These proponents, recalling AIMVAL's similar recommendations, argued for faster, more lethal IR- and radar-guided missiles, as well as improved aircraft radars.[58] Still others saw no need to distinguish between the two requirements. "ACEVAL," one enthusiastic general reported, "strongly inferred that more quality and quantity are required."[59]

There were several, though, who cautioned against drawing anything meaningful from either AIMVAL or ACEVAL. For example, the authors of TAC's final report on ACEVAL warned that the tests were not appropriate representations of future air combat and that the results could not be "directly applied to any actual air-to-air environment."[60] Another senior USAF officer intimated that the JTF performed only perfunctory analysis of the results, complaining that the ACEVAL summary briefing "makes the point several times that numbers are the determining factor in the outcome of air combat. It is obvious that numbers were a dominating factor in determining the outcome of the mock combat in the test. What is not so obvious is what caused numbers to be so important."[61]

Indeed, test officials acknowledged during congressional testimony in April 1978 that one of the tests' key dependent variables, exchange ratio, was ultimately found to be "misleading by itself and insensitive to many factors."[62] After having devoted almost 5,900 sorties to the task, test officials admitted that they now knew a great deal about short-range air combat, but had analyzed "perhaps [only] 2 inches on the yardstick of air superiority" that pilots would face in the future.[63] However, lacking the necessary additional funding and authority to conduct further analysis, and having addressed Congress's immediate test demands, the formal AIMVAL–ACEVAL results were brusquely filed away. They were occasionally dusted off as needed to justify future weapons acquisitions like the AMRAAM.[64]

Almost a half-decade later, interest in AIMVAL–ACEVAL suddenly resurfaced. A group of Pentagon insiders known as the "Reformers" was growing concerned about the DOD's seemingly insatiable appetite for exquisite—and exquisitely priced—technology. The US military, they warned, was on a "curve of unilateral disarmament," and the problem was especially acute in the Air Force and Navy's fighter force. Advanced fighters like the Eagle and Tomcat were so expensive that the services could only afford to purchase limited quantities of them. Exacerbating matters, the complex aircraft also came with burdensome maintenance requirements that further reduced the service's effective force. The net result, according to the Reformers, was that the US military possessed only a "phantom fleet" of fighter aircraft.[65]

As an alternative to the services' favored high-end weapons, the Reformers proposed instead acquiring a fleet of cheap, "brilliantly simple" aircraft. These aircraft, which included the aggressors' F-5 that was used during AIMVAL–ACEVAL, might not match well individually against a state-of-the-art F-14 or F-15, but force-for-force, they were undeniably effective, at least according to the Reformers' interpretation of the tests' results. After all, they pointed out, ACEVAL's law reflected the importance of numbers in combat.[66] For the cost of one F-15, the Air Force could buy four cheaper F-5 fighters. Then, because the F-5 was easier to maintain, the Reformers explained, it could be flown at a higher sortie rate. When armed with relatively inexpensive but lethal short-range IR-guided missiles and a powerful gun, these brilliantly simple aircraft would provide just enough technology to answer America's tactical fighter requirement, but at a much more affordable price that would finally allow the nation to field sufficient numbers of aircraft to defeat the Soviet hordes.[67]

The Reformers' arguments soon caught the attention of James Fallows, an editor at *The Atlantic Monthly*. Leaders on Capitol Hill were already clamoring for defense reform following the Soviet invasion of Afghanistan and the military's debacle Desert One, the failed attempt to rescue the American hostages from Iran in April 1980. In December of that year, Sen. Sam Nunn (D-GA) declared his frustration with the military's recent underwhelming performance as he opened a set of hearings examining the effect of technology on military readiness.[68] A few months later, a Military

Reform Caucus emerged with the stated goal of uncovering waste and corruption within the US military.[69] Fallows's columns and his award-winning *National Defense* drew on the Reformers' arguments and their interpretations of AIMVAL–ACEVAL to fuel the intensifying debate, which quickly spread to the popular media.[70] The *Chicago Tribune*, for example, reported in December 1981 that during AIMVAL–ACEVAL, "the proud 'air superiority fighters,' F-15s and F-14s, . . . had been fought to all but a draw by a comparatively crude $4 million airplane, the F-5."[71] Two years later, the editors at *Time* elected to put Reformer Chuck Spinney on the cover, his charts looming ominously in the background with the question, "US Defense Spending: Are Billions Being Wasted?" bold in the foreground.[72]

The popularity of the AIMVAL–ACEVAL data, and the Reformers' interpretation of it, confounded those within the Pentagon. The services bristled at the accusation that they were being circumspect with their data, especially after having devoted such intense energy to crafting as fair and as objective a test as possible. Moreover, military officials pointed to the looming Soviet threat and argued that US fighter aircraft destined to fight over central Europe had to possess the specialized (and albeit unfortunately expensive) equipment to fly and attack in bad weather and at night, especially given the premium that the North Atlantic Treaty Organization's forward defense strategy placed on American airpower.[73] However, these counterarguments were usually brushed aside by the popular media as uninteresting minutia. According to the *New York Times*, many inside the Pentagon resorted to calling the Reformers "fuzzy heads" and accused them of "doing a disservice to the country" by forcing "plain vanilla airplanes" and "cheap, throwaway fighters" on the military.[74] When asked how the AIMVAL–ACEVAL results could be used to support the Reformers' position, an internal report completed in 1981 at the behest of the principal deputy undersecretary of defense for research and engineering—the same DDR&E organization originally responsible for AIMVAL–ACEVAL—matter-of-factly concluded that the two tests were "badly flawed."[75]

As described earlier, the limitations of the tests were not unforeseen. For example, one Air Force general had warned during the testing in 1977: "The large scale of the test itself, number of trial repetitions, and bounty of data tend to create the impression that the test results can be taken at face value. Characteristic of such a notion is the attitude that what came out of the test must be right, since we did so much of it and the results did not change."[76] Even after the effects of the test constraints became apparent, however, test officials were reluctant to modify the test design for fears of inflaming service parochialism and inviting Congressional accusations that the military was manipulating the test to achieve a more favorable outcome. The JTF officials trudged along, resigned to completing the mandatory tests while gathering as much *useful* data as possible.[77] In the end, the commander of the tests' blue forces offered his appraisal, "The test objective of quantifying the influence of 'numbers' on engagement outcomes had not only not been achieved, but was 'probably an impossible task.'"[78] It was a less-than-enthusiastic assessment of the nearly year-long, $150M set of tests.[79]

Lessons for the Close Air Support Fly-Off

The AIMVAL–ACEVAL tests failed to answer their original motivating questions, and the results that they generated were sufficiently ambiguous to animate both sides of the defense reform debate of the early 1980s. But the two tests were not a total failure. More than three decades after AIMVAL–ACEVAL, former CSAF Gen Larry Welch explained that the Air Force and its fighter pilots learned some "pretty darn good lessons out of a . . . very badly flawed, politically motivated, Congressionally-directed, horribly expensive test program."[80] Data analysts for the tests shared a similar appraisal, "Everything that came out of [AIMVAL–ACEVAL] was a byproduct. . . . [It] was worth it, as an afterthought, but not for the reasons we ran the test."[81] Congress and the DOD have done much to improve the military testing enterprise since AIMVAL–ACEVAL, yet structural impediments remain. While DOT&E and the Air Force may have already taken some steps to address these limitations for the coming CAS fly-off, it's still worthwhile to examine four critical lessons from AIMVAL–ACEVAL that should inform preparation, execution, and expectations of the pending test.

First, the Air Force must recognize that the two-plane fly-off will do little to quell the public debate over the future of the A-10 and the CAS mission. Instead, the test will likely further enflame the debate, regardless of the results. While every effort should be made to ensure that the test is constructed and executed in a fair and impartial manner, because the test must be conducted by Air Force personnel, accusations that service parochialism and biases unduly influenced the results should be expected. These accusations will be particularly acute because the critical insights from the test—those that reveal unique platform capabilities and vulnerabilities—will necessarily be shielded from the public's (and potential adversaries') eyes. As discussed earlier, these two mitigating factors will exacerbate the interpretive flexibility of the data, just as during AIMVAL–ACEVAL before.

Further muddying the test results, the "human factor" will likely loom large in the CAS fly-off test. Indeed, the opportunity to analyze complex human–human and human–machine interactions under semirealistic conditions is an essential benefit of a live-fly test, distinguishing it from typically cheaper modeling and simulation data-collection alternatives. The Air Force recognized the advantage of turning F-5s and F-15s loose on the Nellis ranges during AIMVAL–ACEVAL, with one general testifying that rather than simply putting all the aircraft and missile data in "a computer, kick[ing] that computer and hav[ing] it spit out a roll of tape that tells you what the outcome was," the live-fly tests revealed the "extremely important . . . human factor" that dramatically influenced the real-world performance of the complex weapons.[82] However, human factors are also notoriously difficult to capture, and often proxy metrics must be used for assessment. With the advocates of the F-35 and the A-10 differing in their assessment of the character of future CAS battles and the pilots' critical tasks therein, it's highly unlikely that the two sides will reach a consensus on the test's dependent variables of interest, which will generate even more ambiguity and contention over the public results.[83]

Second, DOT&E and the Air Force must facilitate excursion testing during the CAS fly-off and then encourage supplemental data analysis following the test. One of the principal failings of AIMVAL–ACEVAL was that once interesting anomalies were observed, the test matrix and schedule were too rigid to permit further investigation. On the surface, the two preidentified critical test metrics seemed reasonable—exchange ratio (number of red killed/number of blue killed) and loss rate (number of blue killed in trials/number of blue entering trials)—but as new dependent variables of interest emerged, there was little opportunity to conduct additional experimentation and analysis to determine their relevance. The laborious negotiation and interservice bargaining that produced the test matrix had reduced the massive tests to an unfortunate "one-shot" design that could identify important trends but possessed scant power to then elucidate those trends.[84]

Unofficial analysis conducted after AIMVAL–ACEVAL suggested that other more significant variables were indeed lurking in the background. "Quantifiable variables such as numbers only accounted for about 10–20 percent of the variation in outcomes," one analyst later concluded, "whereas human factors had 'more than five times the effect on results' compared to variables such as 'force ratio or whether somebody does or doesn't have GCI [ground-controlled intercept].'"[85] The same scheduling and budget pressures that unfortunately curtailed additional investigation and analysis during AIMVAL–ACEVAL will likely be present in the CAS fly-off test. But, if the goal is to maximize potential learning, the Air Force and DOT&E must develop a flexible test matrix that facilitates appropriate additional excursion testing. Additionally, the Air Force and DOT&E should commit to sharing the collected data across the DOD, encouraging others to scour the data looking for critical lurking variables that might further our knowledge of how best to execute current and future CAS.

Third, if the lack of resources to conduct additional analysis was one of AIMVAL–ACEVAL's critical failings, then the freedom that the test officials granted to the participants to experiment with novel tactical solutions was one of the tests' principal strengths. DOT&E and the Air Force would be well-served to encourage similar creativity during the CAS fly-off. During AIMVAL–ACEVAL, TAC officials lauded the pilots' impressive "ingenuity" and their ability to develop stylized tactics that maximized their advantages against their adversary.[86] Because this battle of wits took place on both the blue and red sides, the net effect, however, was a tactical stalemate with neither side accruing a significant advantage over the other for any appreciable duration.[87] While some suggested that the overly complicated tactics were yet another artificiality that generated unrepresentative test data, JTF officials deemed that such "tactics change for change's sake was a sound tactical principle," and that the intense competition among the aircrews helped contribute to the "realism" of the test environment.[88] It also produced a persistent, steep tactical learning curve for the pilots. One AIMVAL–ACEVAL F-15 pilot claimed that the lengthy, rigorous tests accelerated air combat tactics development by at least five years.[89] As one example, early in the ACEVAL trials, the targeting process for a four-ship of Eagles required more than 100 separate intraflight radio transmissions.[90] Throughout the test, the F-15 pilots worked tirelessly to streamline the cumbersome radar employment procedures as they experimented with new "sorting" mechanics and radio calls that would facilitate faster, more flexible targeting.[91] These new tactics subsequently became pillars of successful Eagle employment.

In the CAS arena, the last decade-and-a-half of war has provided the Air Force with a crucible for tactics development, but it has been restricted to relatively permissive environments. As more complex, contested environments emerge, there may be future requirements to execute CAS or CAS-like missions under an adversary's anti-access/area-denial umbrella. The Air Force has suggested that its technologically-sophisticated stealth F-35 is an ideal platform for these challenging contested scenarios, but the tactics to use that technology in a future CAS environment, with all the relevant enterprise components, are still embryonic. Additionally, while current CAS tactics may limit the survivability of the A-10 in contested scenarios, the opportunity to experiment with novel tactics in a robust test environment could identify otherwise unexploited capabilities or enterprise synergies that might enhance the Warthog's utility in a future CAS fight. Freeing the CAS fly-off participants to explore creative options to these challenging tactical problems—both with advanced stealth technology and without, and all within the context of the Army's simultaneous effort to update its doctrine for the A2AD environment—will ensure that the Air Force best capitalizes on the fly-off test opportunity.

Finally, the Air Force must be receptive to any jarring insights that might emerge from the CAS fly-off test. AIMVAL–ACEVAL focused on air combat in the close-range arena. The Air Force's F-15 "Superfighter," purposefully built to triumph in a dogfight against any current or planned Soviet fighter, was expected to easily defeat its F-5 aggressor foe.[92] However, those expectations did not match reality. The AIMVAL–ACEVAL tests vividly illustrated that a relatively simple foe armed with an all-aspect, fire-and-forget missile like the AIM-9L could be lethal to advanced US fighter aircraft.[93] The new missile, some officers predicted, would consequently "revolutionize fighter tactics."[94] It also demanded a sudden shift in weapons acquisition priorities. Rather than continuing to maximize fighter capabilities *in* the short-range environment, the Air Force quickly reoriented and instead began focusing on developing capabilities that would keep its fighters *out* of the short-range environment.[95] The decision to accelerate development of the multitargetable, fire-and-soon-forget AMRAAM was one manifestation of the shift. Another was the reinvigorated emphasis on developing long-range electronic identification technologies spearheaded by the new TAC commander, Gen Wilbur Creech.[96]

In retrospect, the Air Force's rapid reprioritization was a remarkable example of bureaucratic agility. Today's Air Force must be ready to respond similarly to any paradigm-shifting signals that might emerge from the CAS fly-off. Tactics and technologies that were designed to enhance performance in the future CAS environment may not, while other technologies that have been deemed inconsequential may instead demonstrate critical utility. A rigorous test can help the Air Force identify these unforeseen challenges and opportunities, but only if the service designs the CAS fly-off test with an eye toward flexibility, encourages the participants to be creative, and most importantly, focuses, not on justifying a favored platform, but on learning how to operate in future CAS environments. Then, it must act boldly.

The coming head-to-head matchup between the A-10 and the F-35 will do little to resolve the public debate over the future of Air Force CAS. All empirical tests bear the imprint of the social organization in which they were developed and executed; their resulting data are inherently socially constructed. The interpretive flexibility of the military's empirical data is particularly acute due to structural limitations that constrain the military's ability to execute independent, transparent, and appropriately flexible tests. It was true during AIMVAL–ACEVAL 40 years ago, and it will likely be true during the CAS fly-off in early 2018. Nevertheless, the CAS fly-off has potential to be more than just "a silly exercise," assuming DOT&E and Air Force leaders are mindful of four critical lessons from AIMVAL–ACEVAL. The coming CAS fly-off must encourage test flexibility, robust analysis, and participant creativity, and its implications, however disruptive, must be embraced and then acted upon. If so, then the Air Force once again will have an opportunity to learn some "pretty darn good lessons" from a congressionally-mandated test. ✪

Notes

1. For a summary of the Air Force argument, see Derek O'Malley and Andrew Hill, "The A-10, The F-35, and the Future of Close Air Support," *War on the Rocks*, 27 May 2015, http://warontherocks.com/2015/05/the-a-10-the-f-35-and-the-future-of-close-air-support-part-i/; and O'Malley and Hill, "Close Air Support in 2030: Moving Beyond the A-10/F-35 Debate," *War on the Rocks*, 28 May 2015, http://warontherocks.com/2015/05/the-a-10-the-f-35-and-the-future-of-close-air-support-part-ii/. The service later attempted to justify its A-10 retirement plans based on limited maintenance manpower, but the argument was deemed specious by many outside the service; see Brian Everstine, "Air Force: Keeping A-10 Means F-35 Delays, F-16 Cuts," *Air Force Times*, 28 April 2015, https://www.airforcetimes.com/articles/air-force-keeping-a-10-means-f-35-delays-f-16-cuts.

2. "Congress Issues Air Force Sharp Rebuke, Bars A-10 Retirement," *John Q. Public*, 30 September 2015, https://www.jqpublicblog.com/congress-issues-air-force-sharp-rebuke-bars-a-10-retirement/; and Martha McSally, "Saving a Plane That Saves Lives," *New York Times,* 20 April 2015, http://www.nytimes.com/2015/04/20/opinion/saving-a-plane-that-saves-lives.html?_r=0.

3. Lara Seligman, "Welsh: F-35 vs. A-10 Testing a 'Silly Exercise,' " *Defense News*, 24 August 2015, http://www.defensenews.com/story/defense/air-space/support/2015/08/24/welsh-f-35-vs--10-testing--silly-exercise/32292147/; and Brendan McGarry, "Welsh Dismisses F-35, A-10 CAS Contest as 'Silly Exercise,' " *DOD Buzz*, 25 August 2015, http://www.dodbuzz.com/2015/08/25/welsh-dismisses-f-35-a-10-cas-contest-as-silly-exercise/. Others have also questioned the wisdom of the proposed test, but for different reasons. For an example see Robert Preston and Don Kang, "A Close Air Support Flyoff is a Distraction," *War on the Rocks*, 29 July 2016, http://warontherocks.com/2016/07/a-close-air-support-flyoff-is-a-distraction/.

4. "National Defense Authorization Act for Fiscal Year 2017," Report of the Committee on Armed Services, House of Representatives, on H. R. 4909, 30–32, https://www.congress.gov/114/crpt/hrpt537/CRPT-114hrpt537.pdf. On the DOT&E plan to conduct comparative testing, see McGarry, "F-35 and A-10 to Square Off in Close Air Support Tests," *DOD Buzz*, 24 August 2015, http://www.dodbuzz.com/2015/08/24/f-35-and-a-10-to-square-off-in-close-air-support-tests/.

5. McSally, "Why We Need an A-10/F-35 Fly-Off," *Air Force Times*, 14 June 2016, https://www.airforcetimes.com/articles/why-we-need-an-a-10-f-35-fly-off.

6. Oriana Pawlyk, "A-10's Earliest Retirement Reset to 2021: General," *Military.com*, 7 February 2017, http://www.military.com/daily-news/2017/02/07/a10s-earliest-retirement-reset-2021-general.html; and Pawlyk, "A-10 vs. F-35 Flyoff May Begin Next Year: General," *DoD Buzz*, 25 January 2017, https://www.dodbuzz.com/2017/01/25/10-vs-f-35-flyoff-may-begin-next-year-general/.

7. Steven Shapin and Simon Schaffer, *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life* (Princeton, NJ: Princeton University Press, 1985), 344.

8. David Bloor, *Knowledge and Social Imagery*, 2nd ed. (Chicago, IL: University of Chicago Press, 1991), 22; Thomas S. Kuhn, *The Structure of Scientific Revolutions,* 3rd ed. (Chicago: University of Chicago Press, 1996); Robert K. Merton, "Priorities in Scientific Discovery: A Chapter in the Sociology of Science," *American Sociological Review* 22, no. 6 (December 1957): 635–59; Bruno Latour, *Science in Action: How to Follow Scientists and Engineers Through Society* (Cambridge, MA: Harvard University Press,

1987). Social constructivism has also been applied to technology studies; see Trevor Pinch and Wiebe E. Bijker, "The Social Construction of Facts and Artifacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other," in *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, ed. Wiebe E. Bijker, Thomas P. Hughes, and Trevor Pinch (Cambridge, MA: The MIT Press, 1989), 17–50.

9. Bruno Latour and Steve Woolgar, *Laboratory Life: The Construction of Scientific Facts*, 2nd ed. (Princeton, NJ: Princeton University Press, 1986), 243.

10. Joel Best, *Damned Lies and Statistics: Untangling Numbers from the Media, Politicians, and Activists* (Berkeley, CA: University of California Press, 2001); Best, *More Damned Lies and Statistics: How Numbers Confuse Public Issues* (Berkeley, CA: University of California Press, 2004); and Best, "Lies, Calculations and Constructions: Beyond How to Lie with Statistics," *Statistical Science* 20, no. 3: 210–14.

11. Best suggests that the propensity to accuse others of lying with statistics "is often implicitly endorsed in statistics instruction. . . . Students are warned that there are biased people who may deliberately choose to calculate statistics that will lend support to the position they favor." According to Best, this prevalent "statistics-or-lie distinction" is harmful because it "makes an implicit claim that, if statistics are not lies, they must be true—that is, really true in some objective sense." Best, "Lies, Calculations and Constructions," 211.

12. Best, *More Damned Lies and Statistics*, xiii.

13. "There is flexibility in how people think of or interpret artifacts . . . [and] there is flexibility in how artifacts are designed." Pinch and Bijker, "The Social Construction of Facts and Artifacts," 40.

14. Best, *More Damned Lies and Statistics*, 151.

15. Edward Constant, *The Origins of the Turbojet Revolution* (Baltimore, MD: Johns Hopkins University Press, 1980), 8.

16. Walter G. Vincenti, *What Engineers Know and How They Know It: Analytical Studies from Aeronautical History* (Baltimore, MD: Johns Hopkins University Press, 1990).

17. An inflexible, static test design is not conducive to knowledge generation. According to Box and Liu:

> An industrial innovation of major importance . . . comes about as the result of an *investigation* requiring a sequence of experiments. Such research and development is a process of learning: dynamic, not stationary; adaptive, not one-shot. The route by which the objective can be reached is discovered only as the investigation progresses, each subset of experimental runs supplying a basis for deciding the next. Also, the objective itself can change as new knowledge is brought to light (emphasis in original).

George E. P. Box and Patrick Y. T. Liu, "Statistics as a Catalyst to Learning by Scientific Method Part I—An Example," *Journal of Quality Technology* 31, no. 1 (January 1999): 1. See also Donald T. Campbell and Julian C. Stanley, *Experimental and Quasi-Experimental Designs for Research* (Boston, MA: Houghton Mifflin Company, 1963), ch. 5.

18. Howard likened the military leader's challenge to "sail[ing] on in a fog of peace until the last moment. Then probably, when it is too late, the clouds lift and there is land immediately ahead; breakers, probably, and rocks. . . . Such are the problems presented by 'an age of peace.'" Michael Howard, "Military Science in an Age of Peace," *RUSI Journal for Defence Studies* 119, no. 1 (March 1974): 4. Howard's analogy draws on the popular "fog of war" adage in Carl von Clausewitz, *On War*, ed. and trans. Michael Howard and Peter Paret (Princeton, NJ: Princeton University Press, 1976), 140. Even if wars were more frequent, altering technological and doctrinal development based on their lessons might still result in future failure. For example, the French army's spectacular defeat during the Franco–Prussian War of 1870 led to a new offensive doctrine that emphasized the spirit of élan, which itself contributed to the failure on the Western Front during World War I. Alistair Horne, *The Price of Glory: Verdun 1916* (New York: Penguin Books, 1993); and Jack Snyder, "Civil-Military Relations and the Cult of the Offensive, 1914 and 1984," *International Security* 9, no. 1 (June 1984): 108–46. McNamara is often credited (and maligned) for introducing statistical rigor to Department of Defense research; see Alain C. Enthoven and K. Wayne Smith, *How Much Is Enough? Shaping the Defense Program, 1961–1969* (New York: Harper & Row Publishers, 1971).

19. Cited in John A. English, *On Infantry* (New York: Praeger, 1981), 205.

20. These problems are exacerbated when the public suspects military malfeasance and deliberate misrepresentation of data. For an example, see James Burton, *The Pentagon Wars: Reformers Challenge the Old Guard* (Annapolis, MD: Naval Institute Press, 1993). Burton's story of the Army's Bradley fight-

ing vehicle was later made into an HBO film starring Kelsey Grammer, *The Pentagon Wars*. See also the ill-fated Millennium Challenge 2002 exercise, described in Micah Zenko, *Red Team: How to Succeed by Thinking like the Enemy* (New York: Basic Books, 2015), 52–61.

21. For more on AIMVAL–ACEVAL, see Steven Fino, "Doubling Down: AIMVAL–ACEVAL and US Air Force Investment in TacAir post–Vietnam," *Vulcan: The Social History of Military Technology* 2 (2014): 125–161; as well as brief discussions in Barry D. Watts, *Six Decades of Guided Munitions and Battle Networks: Progress and Prospects* (Washington, DC: Center for Strategic and Budgetary Assessments, 2007), 49–50; C. R. Anderegg, *Sierra Hotel: Flying Air Force Fighters in the Decade after Vietnam* (Washington, DC: Air Force History and Museums Program, 2001), 158–64; Brian D. Laslie, *Air Force Way of War: US Tactics and Training after Vietnam* (Lexington, KY: University Press of Kentucky, 2015), 89–92; and Marshall L. Michel, "The Revolt of the Majors: How the Air Force Changed after Vietnam" (PhD diss., Auburn University, 2006), 258–62.

22. Drew Middleton, "Air Force Unveils Fighter Designed to Keep Superiority into the '80's," *New York Times* (27 June 1972); Michel, *Clashes: Air Combat Over North Vietnam, 1965–1972* (Annapolis, MD: Naval Institute Press, 1997), 291–94; Edgar Lewis, "History of the F-15 Eagle: A Corporate Memory," 18 May 1976, 9–11, 35, AF Historical Research Agency (AFHRA) K417.042–18; and "F-15 Rolls Out at St. Louis," *Flight International* (6 July 1972): 11. Development of the Navy's F-14 preceded the F-15 by almost a full year, complicating the Air Force's fighter acquisition efforts; see "Talking Paper on 'Dr. DuBridge Letter to Mr. Packard,' " 12 December 1969, AF Materiel Command/History Office (AFMC/HO) 03936; Jacob Neufeld, *The F-15 Eagle: Origins and Development, 1964–1972* (Washington, DC: Office of Air Force History, 1974): 23–24, AFHRA K417.042-18 (there are two versions of this document; all references are to the original classified [and since declassified] version); Roger K. Rhodarmer, "Oral History Interview," by Neufeld, 29 March 1973, 5, 17–23, AFHRA K239.0512–972; Alexander H. Flax, "Oral History Interview," by James C. Hasdorff and Neufeld, 27 November 1973, 26–28, AFHRA K239.0512-691; and Kenneth P. Werrell, *Chasing the Silver Bullet: US Air Force Weapons Development from Vietnam to Desert Storm* (Washington, DC: Smithsonian Books, 2003), 63–65.

23. Robert C. Mathis, "F-15 Air Superiority Fighter: Presentation for Hon. James R. Schlesinger, secretary of defense," 3 May 1974, AFMC/HO 03887; and D. V. Wells, "Sparrow Missile Program Review," Hearings before the US Senate, Committee on Armed Services, 11 March 1976 (Washington, DC: Government Printing Office [GPO], 1976), 5000–13.

24. Benton K. Partin, "Program Management Directive for Project 670E (Air-to-Air Technology)," 4 September 1973, 2, AFHRA Microfilm 40233; Robert G. Dilger, "CLAW Missile Program Review," Hearings before the US Senate, Committee on Armed Services, 27 March 1974 (Washington, DC: GPO, 1974), 4705–25; Lewis, "History of the F-15 Eagle," 14; and E. J. Griffith, "AIMVAL–ACEVAL: Why/What/How," *Fighter Weapons Review* (Fall 1977): 24. CLAW supposedly stood for "Concept of a Lightweight Aerial Weapon."

25. An off-boresight missile can be cued to a target that is not directly in front of it. J. H. Quinn, "Agile Program Review," Hearings before the US Senate, Committee on Armed Services, 27 March 1974 (Washington, DC: GPO, 1974), 4695–705; Peter Waterman, "Research, Development, Test, and Evaluation: Navy," Hearings before the US House, Subcommittee of the Committee on Appropriations, 25 September 1973 (Washington, DC: GPO, 1973), 794–97; and Malcolm R. Currie, "Statement of the Director of Defense Research and Engineering," Hearings before the US House, Subcommittee of the Committee on Appropriations, 24 September 1973 (Washington, DC: GPO, 1973), 456. Currie, the director of DDR&E, expressed his concerns about the Agile's high price tag, telling Congress, "Estimates indicate that at least a 20-percent reduction (preferably 40 percent) would be necessary to enable procurement of the missile in large quantities." Former CSAF Larry Welch explained that the Navy needed the Agile to be highly maneuverable to compensate for the restricted turning performance of the F-14 Tomcat. Larry D. Welch, interview by author, 10 July 2012; see also James R. Hildreth, "Oral History Interview," by Hasdorff, 27 October 1987, 160–61, AFHRA K239.0512-1772.

26. An all-aspect missile can shoot from any angle relative to the target; prior to the AIM-9L, Sidewinders could only be launched from a limited area behind the target's tail. Ron Westrum, *Sidewinder: Creative Missile Development at China Lake* (Annapolis, MD: Naval Institute Press, 1999), 192–95; William B. Haff, "Sidewinder Program Review," Hearings before the US Senate, Committee on Armed Services, 14 March 1975 (Washington, DC: GPO, 1975), 4619–34; M. O. Beck, "State of the Art," *Fighter Weapons Review* (Winter 1974): 28–33; and W. H. Van Dyke Jr., "Sidewinder Program Review," Hearings

before the US Senate, Committee on Armed Services, 11 March 1976 (Washington, DC: GPO, 1976), 5013–38.

27. "Advanced Short Range Air-to-Air Missile Technology," *Congressional Record* 121, no. 23 (1975): 29370; Julian S. Lake, "ACEVAL–AIMVAL Program Review," Hearings before the US Senate, Committee on Armed Services, 11 March 1976 (Washington, DC: GPO, 1976), 5040; and Griffith, "AIMVAL–ACEVAL," 24–25.

28. *History of the Air Force Test and Evaluation Center, 1 January–31 December 1976*, 1: 213, AFHRA K150.01; Lake, "ACEVAL–AIMVAL Program Review," 5038–39; Griffith, "AIMVAL–ACEVAL," 24–25; Anderegg, *Sierra Hotel,* 159; Robert H. Fay, "AIMVAL–ACEVAL Program Review," Hearings before the US Senate, Committee on Armed Services, 9 March 1977 (Washington, DC: GPO, 1977), 4569; and CSAF/XO message to TAC/CV et al., "ACEVAL/AIMVAL Test Directive" (171237Z April 1975), in *History of the Air Force Test and Evaluation Center, 1 January 1974–31 December 1975,* 24, AFHRA K150.01.

29. *History of the Air Force Test and Evaluation Center, 1 January–31 December 1976,* 1: 213; Lake, "ACEVAL–AIMVAL Program Review," 5038–39; Fay, "AIMVAL–ACEVAL Program Review," 1977, 4569; Anderegg, *Sierra Hotel*, 159; and Griffith, "AIMVAL–ACEVAL," 24–25.

30. Lake also outlined each test's objectives: "Objective of first test (ACEVAL) is to determine the effect of A/C [aircraft] multiples on air combat engagements using contemporary weapons and aircraft. Second test (AIMVAL) will determine operational utility of advanced conceptual short-range air-to-air missiles." COMNAVELECSYSCOM message to CSAF and CNO, "ACEVAL/AIMVAL Joint Test" (022324Z May 1975), in *History of the Air Force Test and Evaluation Center, 1 January 1974–31 December 1975,* 24. The order of the two tests was subsequently switched, with ACEVAL being flown after AIMVAL. Lake's description of the test objectives differed slightly from those in the initial Air Force test message: "ACEVAL is to determine effect of multiple fighters/initial entry conditions in air-to-air engagements. . . . AIMVAL is to compare operational utility of existing and proposed air-to-air missile concepts. All aspect, acquisition, and large off-boresight capabilities are of particular significance in AIMVAL." CSAF/XO message to TAC/CV et al., "ACEVAL/AIMVAL Test Directive."

31. ADTC/XR message to AFSC/TEV, "ACEVAL–AIMVAL Test Plans REF: AFSC/TEV MSG R161900Z Sep 76" (272017Z September 1976), in *History of the Air Force Test and Evaluation Center, 1 January–31 December 1976,* 21; "F-15s, F-5Es Catching Up with F-14 OR Rates at Nellis, Ryan Says," *Aerospace Daily* (3 August 1977); James A. Knight, "Oral History Interview," by James C. Posgate, 30 December 1983, 232, AFHRA K239.0512-970; and Hildreth, "Oral History Interview," 161.

32. CSAF/XO message to TAC/CV, "AIMVAL/ACEVAL F-15s" (312111Z December 1975), in "Lessons Learned Symposium, 1974 (AFSC)," AFMC/HO 03951; and Barry Swarts, "Interest Paper on AIMVAL/ACEVAL," 14 July 1976, 2–3, in *History of ADCOM, 1 January–31 December 1976,* 6, AFHRA K410.011.

33. Lake, "ACEVAL-AIMVAL Program Review," 5056; and Fay, "AIMVAL–ACEVAL Program Review," 1977, 4579.

34. COMNAVELECSYSCOM message to CSAF and CNO, "ACEVAL/AIMVAL Joint Test"; and Hildreth, "Oral History Interview," 161–62.

35. Lake, "ACEVAL–AIMVAL Program Review," 5042, 5049; and ADTC/XR message to AFSC/TEV, "ACEVAL–AIMVAL Test Plans." The Weapons System Evaluation Group (WSEG) and the Institute for Defense Analysis (IDA) were tasked to provide analytical support for the pending evaluations.

36. Lake, "ACEVAL–AIMVAL Program Review," 5039, 5042; and *History of the Air Force Test and Evaluation Center*, *1 January 1976–31 December 1976*, 1: 218–19. Cubic Corporation's ACMI system was an updated version of a similar system developed a few years earlier for the USN. The Navy's system, called ACMR (Air Combat Maneuvering Range), was developed to help pilots visualize weapons employment zones in accordance with the recommendations of the Ault Report. Frank Ault, *Report of the Air-to-Air Missile System Capability Review, July–November 1968* (Naval Air Systems Command, 1969), http://www.history.navy.mil/branches/org4-25.htm. Describing air combat debriefs prior to ACMI, Anderegg observed, "No one can lie to himself better than a fighter pilot about to pull the trigger." Wallace, one of the eight AIMVAL–ACEVAL Eagle pilots, explained that winning the debrief was all about telling a believable story, "If you could lie better than anybody else, they couldn't refute you." Alluding to a fighter pilot's propensity to use his hands to reconstruct the motion of the fighters during the fight, Welch noted, "If you could get your hand back [farther than the other guy], then you could turn tighter." Anderegg, *Sierra Hotel*, 104, 108–9; Jere Wallace, interview by author, 3 October 2013; and L. Welch, interview by author, 1 October 2013.

37. Fay, "AIMVAL–ACEVAL Program Review," 1977, 4575.

38. Ibid.; Anderegg, *Sierra Hotel,* 108–10; Griffith, "AIMVAL–ACEVAL," 26–27; Taylor, "Air Combat Maneuvering Instrumentation (ACMI)," 1 October 1975, AFHRA 168.7339–79; David Everson, *AIMVAL Final Report,* 7–10, in *History of the Tactical Air Command, January–December 1977,* 2, AFHRA K417.01; James Quick, "Cleared in Hot," *Fighter Weapons Review* (Winter 1974): 9–17; Chuck Turner, "ACMI Update," *Fighter Weapons Review* (Summer 1977): 17–22; Robinson Risner, "Oral History Interview," by Mark C. Cleary, 1 March 1983, 182, AFHRA K239.0512–1370; "Dogfight Pilot Training at Nellis," *Las Vegas Review Journal* (21 December 1976); and "Nellis Pilots Given New Battle Training," *Las Vegas Sun* (29 December 1976).

39. TAC/DR message to AFTEC/CC, "ACEVAL/AIMVAL Preliminary Test Plan Review" (241945Z March 1976), in *History of the Air Force Test and Evaluation Center, 1 January–31 December 1976,* 21; and Robert T. Marsh letter to AFTEC/CC, "AFSC Review of ACEVAL/AIMVAL Preliminary Test Plan (Your 272126Z Jan 76)," 17 March 1976, attachment to Gen William J. Evans letter to HQ USAF/CV, "AIMVAL," 17 March 1976, AFHRA K168.7339-79. The pilots occasionally complained that the red forces' missiles were too effective with ACMI—one pilot said the aggressor force was given "hittles" instead of "missiles." Thomas Sokol, interview by author, 4 August 2013.

40. Having delayed the two tests for almost a year while waiting on ACMI, there was little stomach in the Pentagon for postponing the tests further to gain a larger ACMI test-space—Congress demanded the test results and the services needed to deliver them if they hoped to gain the funding that their acquisition plans required. ACEVAL AIMVAL JTF message to DDRE, "ACEVAL–AIMVAL Monthly Progress Report (as of 6 Jan 76)" (061830Z January 1976), in *History of the Air Force Test and Evaluation Center, 1 January–31 December 1976,* 21; and Fay, "AIMVAL-ACEVAL Program Review," 1977, 4571. The Air Force was also in the process of constructing an East coast ACMI range for use by both Navy and Air Force aircraft, but it would not become operational until early 1977; Dave Husted, "1st TFW Inherits Pilot Training System," *The Flyer* (3 March 1977), in *History of the 1st Tactical Fighter Wing, January–March 1977,* 2, AFHRA K-WG-1-HI.

41. Lake, "ACEVAL–AIMVAL Program Review," 5042–43; Fay, "AIMVAL–ACEVAL Program Review," 1977, 4571–72; Robert P. McKenzie and Hildreth, *ACEVAL Final Report*, 1: sec. 3, 1–5, in *History of the Air Force Test and Evaluation Center, 1 January–31 December 1977,* 12, AFHRA K150.01; Stephen Dvorchak, interview by author, 3 August 2012; and William Sparks, interview by author, 3 August 2012. To enforce aircrew adherence to the VID restriction during the tests, officials planned to have "random nonexercise aircraft in the exercise area." Shooting down one of the "nonplayers" would, according to one test official, result in "a bad day" for the offending aircrew.

42. During Vietnam, aircrews often had to obtain a visual identification before engaging the enemy and, even though US aircrews "were not too happy" about being unable to employ their longer-range, radar-guided Sparrow missiles as once envisioned, most abided by the combat restriction, saying they "preferred this to shooting down one of their own aircraft by mistake." "Pilots Describe Downing of MiG's: 8 Get Decorations and Tell How Missiles Hit Foe." *New York Times* (12 July 1965): 3; and William W. Momyer memorandum for Gen Ellis, "CORONA HARVEST (Out-Country Air Operations, Southeast Asia, 1 January 1965–31 March 1968," 4, 24, AFHRA K239.031-98.

43. *History of the Air Force Test and Evaluation Center, 1 January–31 December 1976,* 1: 216–17; and TAC/DR message to CSAF/XOO, "ACEVAL/AIMVAL Test Constraints" (050200Z May 1976), in *History of the Air Force Test and Evaluation Center, 1 January–31 December 1976,* 21. The Air Force responded with its own VID-enhancing equipment, installed just in time for ACEVAL. Known as the "Eagle Eye," the simple system consisted of an off-the-shelf, six-power rifle scope mounted next to the F-15's Heads Up Display (HUD); see Tim O'Keefe Jr., "Eagle Eye," *Fighter Weapons Review* (Fall 1978): 27–29; Everson, *ACEVAL Final Report*, 4, in *History of the Tactical Air Command, January–December 1977,* 2, AFHRA K417.01; McKenzie and Hildreth, *ACEVAL Final Report*, 1: sec. 3, 6; Anderegg, *Sierra Hotel*, 161; and Frederick C. Blesse, "Corona Ace Oral History Interview," by Gordon F. Nelson, 14 February 1977, 84–85, AFHRA K239.0512-1077.

44. These and other test constraints were detailed in: SAF/SA message to AFTEC/CC, "Review of ACEVAL-AIMVAL Preliminary Test Plan"; TAC/DR message to AFTEC/CC, "ACEVAL/AIMVAL Preliminary Test Plan"; Fay, "AIMVAL/ACEVAL Program Review," Hearings before the US Senate, Committee on Armed Services, 5 April 1978 (Washington, DC: GPO, 1978), 5202–3, 5220–21; Lake, "ACEVAL–AIMVAL Program Review," 5049; and ADTC/XR message to AFSC/TEV, "ACEVAL–AIMVAL Test Plans." See also

Walter Kross, *Military Reform: The High-Tech Debate in Tactical Air Forces* (Washington, DC: National Defense University Press, 1985), 104–5.

45. SAF/SA explained its concern, "Our fundamental objection to use of the term exchange ratio is based on the fact that actual aircraft killed is not portrayed and therefore indiscriminate use of the term can lead to poorly founded conclusions. The relevant measure of force effectiveness . . . is more related to absolute attrition rates than to exchange ratio." SAF/SA message to AFTEC/CC, "Review of ACEVAL–AIMVAL Preliminary Test Plan." On the test measures, see Fay, "AIMVAL/ACEVAL Program Review," 1978, 5199.

46. TAC/DR message to AFTEC/CC, "ACEVAL/AIMVAL Preliminary Test Plan."

47. George Haering, "Aim/Ace," *Topgun Journal* 1, no. 3 (Fall 1977): 15.

48. Recorded in Lake, "ACEVAL–AIMVAL Program Review," 5050.

49. Quoted in *History of the Air Force Test and Evaluation Center, 1 January–31 December 1977,* 1: 271. SAF/SA officials similarly warned in an internal communique, "The test should not be advertised as something it is not." SAF/SA message to AFTEC/CC, "Review of ACEVAL–AIMVAL Preliminary Test Plan." TAC officials likewise noted that it was "imperative that the impact of the test constraints be highlighted." TAC/DR message to AFTEC/CC, "ACEVAL/AIMVAL Preliminary Test Plan."

50. Recorded in Fay, "AIMVAL/ACEVAL Program Review," 1977, 4571.

51. Ernest E. Tissot and Hildreth, *AIMVAL Final Report*, 6 September 1977, 1: sec. 3, 1–6, in *History of the Air Force Test and Evaluation Center, 1 January–31 December 1977,* 14; Everson, *AIMVAL Final Report*, 5–7, 12–14; Lake, "ACEVAL–AIMVAL Program Review," 5050, 5052; and Fay, "AIMVAL/ACEVAL Program Review," 1977, 4573. The Aggressor squadrons consisted of specially trained pilots who mimicked Soviet tactics during training events with other Air Force units; the F-5Es that the aggressors flew simulated the Soviets' MiG-21 fighter. On the Aggressor units, see Jerry H. Nabors, "Aggressor Squadron Briefing," Hearings before the US Senate, Committee on Armed Services, 9 March 1976 (Washington, DC: GPO, 1976), 4907–20; Anderegg, *Sierra Hotel,* 71–88; and Laslie, *Air Force Way of War*, 44–51.

52. *History of the Air Force Test and Evaluation Center, 1 January–31 December 1977,* 1: 273.

53. Fay, "AIMVAL/ACEVAL Program Review," 1978, 5206–10, 5225; Newell, "AIMVAL-ACEVAL Results/Lessons Learned," 9 September 1983, 1, AFHRA K168.03-2107; Jasper A. Welch Jr., interview by author, 8 June 2012; Hildreth, "Oral History," 165–66; Hildreth letter to TAC/CV, "AIMVAL Final Report Recommendations," 28 November 1977, AFHRA 168.7339–79; Burt Munger, "Advanced Medium Range Air-to-Air Missile (AMRAAM)," Hearings before the US House, Committee on Armed Services, Hearings on Military Posture and H. R. 10929, 27 February 1978 (Washington, DC: GPO, 1978), 436–54; Robert M. Bond, "Advanced Medium Range Air to Air Missile," Hearings before the US Senate, Subcommittee of the Committee on Appropriations, 17 July 1978 (Washington, DC: GPO, 1978), 348–49, 358; William Perry, "Impact of Technology on Military Manpower Requirements, Readiness and Operations," Hearings before the US Senate, Subcommittee on Manpower and Personnel of the Committee on Armed Services, 4 December 1980 (Washington, DC: GPO, 1980), 5, 41; Fay, "AIMVAL–ACEVAL Final Report Briefing," Hearings before the US House, Committee on Armed Services, 27 February 1978 (Washington, DC: GPO, 1978), 430; J. F. O'Hara, "Briefing," Hearings before the US House, Committee on Armed Services, 9 March 1978 (Washington, DC: GPO, 1978), 1018–27; and Tissot and Hildreth, *AIMVAL Final Report,* 1: sec. 5, 1.

54. Fay, "AIMVAL–ACEVAL Program Review," 1977, 4565; Everson, *ACEVAL Final Report,* 4–10, 28; and McKenzie and Hildreth, *ACEVAL Final Report*, 1: sec. 3, 1–8, in *History of the Air Force Test and Evaluation Center, 1 January–31 December 1977,* 12.

55. Dvorchak, e-mail to author, 9 February 2012; and Fay, "AIMVAL–ACEVAL Program Review," 1978, 5211–12.

56. Dvorchak is quoted in Watts, "Doctrine, Technology, and War" (presented at the Air and Space Doctrinal Symposium, Maxwell AFB, AL, 1996), n65, http://www.airpower.maxwell.af.mil/airchronicles/cc/watts.html.

57. Newell, "AIMVAL–ACEVAL Results," 3.

58. Ibid., 3–4; and Blesse, "The Changing World of Air Combat," *Air Force Magazine* (October 1977): 34.

59. TFWC/CC message to TAC/CV, "Recap of ACEVAL–AIMVAL Briefings Week of 27 Feb–3 Mar 78" (070200Z March 1978), AFHRA 168.7339–79; and Fay, "AIMVAL–ACEVAL Program Review," 1978, 5208.

60. Everson, *ACEVAL Final Report*, 14. The JTF's final report also cast doubt on the test's outcome: "ACEVAL was a *test* and therefore had constraints. . . . The data trends, in a relative comparison, are all that are usable in applying the ACEVAL results to projected conflicts" (emphasis in original). McKenzie and Hildreth, *ACEVAL Final Report*, 1: sec. 7, 21.

61. J. Welch letter to AF/XO, "AIMVAL Analysis and Evaluation," 5 December 1977, 2–3, in *History of the USAF Tactical Fighter Weapons Center, 1977*, 2, AFHRA K417.0735.

62. Fay, "AIMVAL-ACEVAL Program Review," 1978, 5199, 5201, 5211–12. Describing the analytical difficulties associated with the tests' data, Fay told Congress: "I would like to point out, sir, that we spent 2 years getting prepared for ACEVAL, 6 months running the test, 2 days to reduce this data, and 2 months to figure out how to say it, sir."

63. Fay, "AIMVAL–ACEVAL Final Report Briefing," 435; and Watts, *Six Decades*, 50.

64. The AIMVAL–ACEVAL findings were reportedly "well received by the Congressmen and staffers" during a set of 1978 Congressional hearings, and "substantially justified the AMRAAM program in FY79 [fiscal year 1979]." TFWC/CC message to TAC/CV, "Recap of ACEVAL–AIMVAL Briefings"; and Fay, "AIMVAL–ACEVAL Final Report Briefing," 430–31.

65. Franklin C. Spinney, "Impact of Technology on Military Manpower Requirements, Readiness and Operations," Hearings before the US Senate, Subcommittee on Manpower and Personnel of the Committee on Armed Services, 4 December 1980 (Washington, DC: GPO, 1980), 106–110 (see also "Defense Facts of Life," DTIC ADA111544); James Fallows, *National Defense* (New York: Random House, 1981), 42–43, 100; Robert Coram, *Boyd: The Fighter Pilot Who Changed the Art of War* (Boston: Little, Brown and Company, 2002), 345–50; and Michel, "Revolt of the Majors," 326–30, 338.

66. Coram, *Boyd*, 348; and Michel, "Revolt of the Majors," 260–62. Coram noted that using the Pentagon's own experimental data against it was one of the Reformers' favorite tactics.

67. The Reformers' first attempt at pushing the Air Force to acquire a "brilliantly simple" airframe was the Lightweight Fighter, but that effort was foiled when the service began saddling the winning YF-16 prototype with heavy and expensive electronics and ground-attack accoutrements. The F-5E represented an even more austere platform. Coram, *Boyd*, 305–13; Spinney, "Impact of Technology," 92–93; Glenn A. Kent, "Oral History Interview," by Neufeld, 6 August 1974, 15–19, AFHRA K239.0512–970; Michel, "Revolt of the Majors," 81, 178–82, 261–62, 337–39; and Charles E. Myers Jr., "Tactical Air Warfare," Hearings before the US House, Task Force on National Security and International Affairs of the Committee on the Budget, 21 June 1977 (Washington, DC: GPO, 1977), 25.

68. Sam Nunn, "Impact of Technology on Military Manpower Requirements, Readiness and Operations," Opening Statement of Hearings before the US Senate, Subcommittee on Manpower and Personnel of the Committee on Armed Services, 4 December 1980 (Washington, DC: GPO, 1980), 2.

69. See, for example, Winslow T. Wheeler and Lawrence J. Korb, *Military Reform: A Reference Handbook* (Westport, CT: Praeger Security International, 2007); and Gary Hart and William S. Lind, *America Can Win: The Case for Military Reform* (Chevy Chase, MD: Adler and Adler, 1986).

70. James M. Fallows, "Muscle-Bound Superpower," *Atlantic Monthly* 244 (October 1979): 59; Fallows, "America's High-Tech Weaponry," *Atlantic Monthly* 247 (May 1981): 21–33; Fallows, "I Fly with the Eagles," *Atlantic Monthly* 248 (November 1981): 70–77; Fallows, *National Defense* (New York: Random House, 1981); Coram, *Boyd*, 358; and Michel, "Revolt of the Majors," 339–45.

71. James Coates and Bill Neikirk, "Cheaper Jets Shoot Down Claims for New Models: High-tech Fighters Score Low in 'Combat,' " *Chicago Tribune* (7 December 1981).

72. Characteristic of the statistics feeding the frothing debate, the *Time* article noted that after accounting for inflation, the DOD was spending $4 billion more dollars in 1983 to buy 95 percent fewer aircraft than it had in 1951. Walter Isaacson, Evan Thomas, Bruce W. Nelan, and Christopher Redman, "The Winds of Reform," *Time* 121, no. 10 (7 March 1983): 22–35. If the trend continued, one aerospace industry specialist satirically predicted, "In the year 2054, the entire defense budget will purchase just one aircraft. This aircraft will have to be shared by the Air Force and Navy 3 1/2 days each per week except for leap year, when it will be made available to the Marines for the extra day." Norman R. Augustine, *Augustine's Laws,* 6th ed. (Reston, VA: American Institute of Aeronautics and Astronautics, Inc., 1997), 107. Michel concluded that the Reformers had successfully convinced the public that their battle was "a Manichean contest of good vs. evil, of honest men . . . fighting against a cabal of corrupt military officers and contractors." Michel, "Revolt of the Majors," 299.

73. Kross, *Military Reform,* 143–45; Kross, "Military Reform: Past and Present," *Air University Review* (August 1981), http://www.airpower.maxwell.af.mil/airchronicles/aureview/1981/jul-aug/kross.htm; Perry, "Impact of Technology," 9, 40, 48; Anderegg, "Meeting the Threat: Sophistication vs Simplicity," *Fighter Weapons Review* (Fall 1982): 2, 6; and John T. Correll, "The Reformers," *Air Force Magazine* 91, no. 2 (February 2008): 43. Correll noted that the simple, highly-maneuverable aircraft touted by the Reformers might have been "perfectly suited to an imaginary war in which aerobatic fighters dueled in clear skies on sunny days," coincidentally the flight conditions during AIMVAL–ACEVAL, but the "simple" aircraft would have been of little use in midwinter Central Europe in which "airmen could count on no more than three flying hours a day in which lighting and weather conditions would allow visibility of more than 3.5 miles."

74. Charles Mohr, "Drop in US Arms Spurs Debate on Military Policy: Decline in Numbers of US Weapons Spurs Debate on Quality vs. Quantity," *New York Times* (24 October 1982). See also Kross, *Military Reform*, 104. Others labeled the Reformers "Luddites and antitechnology" and "dark and satanic forces." Coram, *Boyd*, 353, 357.

75. The report later noted, "Even with all these flaws, AIMVAL and, particularly, ACEVAL were very useful beginnings." Thomas S. Amlie, "A Non-Statistical Look at AIMVAL/ACEVAL," 3 February 1981, 1, AFHRA K168.03-2107. Michel argued that in contrast to the Reformers, senior USAF leaders "realized the service's arguments were too complex and nuanced for the general public"; consequently, "they worked closely with the administration . . . to develop ways to appeal to a different audience, the Congress." In the end, the USAF's strategy prevailed. Michel, "Revolt of the Majors," 10–11.

76. J. Welch letter to AF/XO, "AIMVAL Analysis and Evaluation," 2.

77. L. Welch, interview by author, 10 July 2012; and Fay, "AIMVAL–ACEVAL Program Review," 1977, 4577–78.

78. Quoted in Watts, *Six Decades,* 50.

79. The final price tag of AIMVAL–ACEVAL is ambiguous, but according to some sources, the bill for the two tests eclipsed $150 million, more than triple the original price tag. See: AFSC/CS message to ADTC, "ACEVAL/AIMVAL Test Plan" (052310Z February 1976), in *History of the Air Force Test and Evaluation Center, 1 January–31 December 1976,* 21; DSAF/OIP message to AIG, "ACEVAL/AIMVAL News Release" (111943Z June 1976), in *History of the Air Force Test and Evaluation Center, 1 January–31 December 1976,* 22; "Point Paper on the ACEVAL Flight Trials," 3 February 1981, AFHRA K168.03-2107; Lake, "ACEVAL–AIMVAL Program Review," 5044; and Fay, "ACEVAL–AIMVAL Final Report Briefing," 420.

80. L. Welch, interview by author, 10 July 2012.

81. Dvorchak, interview; and Sparks, interview.

82. Fay, "AIMVAL-ACEVAL Program Review," 1977, 4578; and Fay, "AIMVAL–ACEVAL Program Review," 1978, 5217.

83. The varying assessments of the future CAS battlespace and the pilots' tasks therein are reflected in the language used to describe the F-35 and the A-10. The F-35 Joint Program Office touts the F-35 as being "designed 'with the entire battlespace in mind'—it is equipped with advanced stealth, integrated avionics and an integrated sensor package, which will provide the pilot enhanced situational awareness." According to former CSAF Welsh, these advanced capabilities will be essential since "the F-35's mission in the close air support arena will be to do high-threat close air support in a contested environment that the A-10 will not be able to survive in." In contrast, when describing the F-35/A-10 fly-off, McSally emphasized the requirement to evaluate "continuous weapons delivery, comparisons of extended time over target, survivability from simulated direct hits, and low-altitude employment, including 'shows of force' and strafe. In addition, CSAR missions specifically need to test the critical rescue mission commander role that A-10s fill today, which includes locating and protecting the isolated personnel while coordinating all aspects of a potentially complex CSAR mission." Seligman, "Welsh: F-35 vs. A-10 Testing a 'Silly Exercise' "; McGarry, "Welsh Dismisses F-35, A-10 CAS Contest"; and McSally, "Why We Need an A-10/F-35 Fly-Off."

84. Box and Liu, "Statistics as a Catalyst to Learning."

85. Dvorchak's article, "Getting it on in the All-Aspect Arena," *Tactical Analysis Bulletin* (79:2), is cited in Watts, *Six Decades*, 50. Human factors often refer to the pilots' situational awareness, or their understanding of and ability to process the rapidly changing environment around them. See also Fay, "AIMVAL–ACEVAL Final Report," 435; J. Welch letter to AF/XO, "AIMVAL Analysis and Evaluation," 2–3; and Fay, "AIMVAL–ACEVAL Program Review," 1978, 5212–13. On the importance of situational

awareness in air combat, see Mike Spick, *The Ace Factor: Air Combat and the Role of Situational Awareness* (Annapolis, MD: Naval Institute Press, 1988); Watts, "Doctrine, Technology, and War"; and Watts, *Six Decades*, 52–54.

86. Everson, *ACEVAL Final Report*, 10–11.

87. Watts, "Doctrine, Technology, and War."

88. Tissot and Hildreth, *AIMVAL Final Report*, 1: sec. 3, 6; McKenzie and Hildreth, *ACEVAL Final Report*, 1: sec. 6, 2–3, 30 and sec. 7, 18; and Everson, *ACEVAL Final Report*, 10–11. One pilot compared the test scenarios to "a shootout in an isolated tennis court." J. Welch letter to McMullen, 8 March 1977, AFHRA 168.7339-79; and Thomas H. McMullen letter to Dixon, 15 March 1977, AFHRA 168.7339–79.

89. Sokol, interview; Dvorchak, interview; Sparks, interview; and Jeff Cliver, interview by author, 3 August 2012. Cliver offered another perspective on the tests' impact: "We made eight guys pretty proficient, as proficient as you could get. And God only knows how many lives and systems they touched as they proceeded on through their Air Force careers. So that's kind of cool."

90. Dvorchak, interview.

91. Cliver, interview; Dvorchak, interview; Sparks, interview; and Sokol, interview. The AIMVAL–ACEVAL pilots realized that the "name of the game is sorting. If you sort, you win." The test results agreed. On the occasions when the Eagles failed to sort and instead all locked on to a single target, one data analyst recalled "the *best* they ever did . . . was lose three [F-15s]. . . . When they locked on [to] three out of four [aggressors], they kicked ass." The pilots developed other radar tactics, too. For example, Cliver earned a reputation during ACEVAL for being the first pilot to get a radar contact but the last pilot to ever get a radar lock. He also, on average, had the shortest time from when he took his lock to when he fired his first missile. Although counterintuitive at first, it proved to be a recipe for success; Cliver was one of the most lethal Eagle pilots in the test. In contrast, the worst performing Eagle pilot was on average the last to get a radar contact, first to go into radar track, and spent the longest time in track before firing his missile.

92. Robert J. Hoag, "Superfighter," *Fighter Weapons Review* (Summer 1974): 18–30.

93. One engagement, flown as practice for the upcoming ACEVAL portion of the tests, was particularly illustrative of the increased lethality within the short-range environment. The trial lasted less than two minutes before all eight aircraft, four Eagles and four aggressors, were killed, the last Eagle the "victim of a dead man" because his aggressor target managed to fire a simulated Sidewinder just moments before being "killed" by the Eagle's missile. The pilots and analysts dubbed the trial "The Towering Inferno" (some news reports mistakenly termed the infamous four-against-four engagement the "Towering Infernal") after the popular 1974 disaster film, and it was frequently replayed for distinguished visitors using the playback capability of ACMI. Anderegg, *Sierra Hotel,* 159; Fay, "AIMVAL-ACEVAL Program Review," 1978, 5221–23; "No-Win War at Dogbone Lake," *US News and World Report* (9 January 1978): 56–57; Robert Kaylor, "Mock Dogfights Test Latest Jet Fighters," *Sarasota Herald-Tribune* (7 May 1978); and "Air Force Tried out Controversial Planes," *Beaver County (PA) Times* (7 May 1978).

94. Van Dyke, "Sidewinder Program Review," 5028; Tissot and Hildreth, *AIMVAL Final Report,* 1: sec. 5, 1; and Fay, "AIMVAL–ACEVAL Program Review," 1978, 5208. Having served as the commander of the Air Force's first operational F-15 wing, Welch recalled that when the Eagles started flying against the AIM-9L threat, "all these tactics, all of our experiences, everything we've taught each other goes out the window." L. Welch, interview, 10 July 2012. See also "DACT Lessons Learned," Memorandum for Record, in *History of the 27th Tactical Fighter Squadron, April–June 1976, History of the 1st Tactical Fighter Wing, April–June 1976,* 1, AFHRA K-WG-1-HI.

95. Hildreth letter to TAC/CV, "AIMVAL Final Report Recommendations," 28 November 1977, AFHRA 168.7339–79; Munger, "Advanced Medium-Range Air-to-Air Missile," 436–54; Bond, "Advanced Medium Range Air to Air Missile," 348–49, 358; and Perry, "Impact of Technology," 5, 41.

96. "[Gen. Wilbur Creech] seemed to feel that the JTF underestimated [the identification problem] by an order of magnitude. . . . Further he was adamant that present IFF equipment, procedures, reliability and development were inadequate." TFWC/CC message to TAC/CV, "Recap of ACEVAL–AIMVAL Briefings." On subsequent EID efforts, see Werrell, *Chasing the Silver Bullet,* 70–71.

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