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The Enduring Need for Electronic Attack in Air Operations

POLICY BRIEF

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How will the U.S. military penetrate heavily defended airspace in future military operations? Declining defense budgets combined with advances by emerging threats that diminish the effectiveness of stealth technology are putting at risk current plans by the Department of Defense (DOD) to field large numbers of "fifth-generation" fighters. As a result, DOD will be faced with tough tradeoffs to determine the best mix of stealth, electronic attack and other means necessary to defeat the increasingly capable air defense systems that are proliferating throughout the world.

Some potential U.S. adversaries are fielding highly capable Integrated Air Defense Systems (IADS) built around modern, indigenously produced fighter aircraft; advanced, multi-frequency radar for target acquisition and fire control; and highly accurate surface-to-air missiles (SAMs) with increasingly long reach. In particular, "double-digit" SAMs have developed so rapidly that they have eroded some of the advantages of the stealth aircraft designed and fielded to defeat earlier IADS. In essence, this is the result of advances in electronics and computer processing that have occurred much more rapidly than advances in aeronautics, a trend that seems likely to continue well into the future.[1] Furthermore, these electronic advances have routinely been less costly by a large multiple.

For the past three decades the United States has made enormous investments in stealth technology, an effort to greatly reduce the radar cross section (RCS) of attacking aircraft making them very difficult for threat radar to detect in sufficient time to react. But as the F-22 and the F-35 Joint Strike Fighter (JSF) show, stealth is expensive, developmental times are lengthy, and stealth is hard to improve once an aircraft leaves the production line. By contrast, modern IADS with multi-frequency radar, increasingly high computer processing speeds, and double-digit SAMs have advanced in lethality at a rapid rate. They can be expected to continue to do so, steadily eroding the advantages of stealth.

Stealth will continue to be an important component of strike warfare, but stealth alone will not be able to counter ever-more capable IADS threats. It will have to be complemented with newer electronic attack assets to ensure that future air campaigns can be successfully conducted. Therefore, the Department of Defense should:

- Commit to a doctrinal and investment program that recognizes that both electronic attack and electronic protection will be required to successfully penetrate future anti-access/aerial denial (A2/AD) environments.
- Create doctrinal and operational integration among the various air components and across the various platform communities.
- Prioritize development of the Next Generation Jammer (NGJ) and other similar capabilities that emerge.
- Change acquisition policy so that the rapid advancements in electronic systems can be quickly operationalized.

Future Threats to U.S. Military Capabilities

Since 2001, much of the U.S. military's warfighting capability has understandably focused on defeating insurgents who were inflicting serious casualties on U.S. ground forces. But these insurgents lacked air power and fielded only primitive air defenses. U.S air power, including unmanned drones, operated with impunity in both Afghanistan and Iraq. Yet many analysts believe that in future military operations the United States will face very different and much more capable adversaries.[2] Given the immense amount of energy and resources it has devoted to counterinsurgency in the last decade, the U.S. military will have to make sweeping adjustments to understand and accommodate these new potential threats. In considering the conduct of future air operations against a technologically advanced enemy, defense planners are particularly concerned about future adversaries with three types of capabilities: A2/AD assets, double-digit SAMs and highly agile multi-band radar.

ANTI-ACCESS/AREA DENIAL (A2/AD)

As modern weapons have become more capable, they have generally become more lethal and able to strike over much longer ranges. In World War II, for example, the standard tank battle involved engagements at less than 500 meters, well within visual range of the on-board direct sighting systems. By Operation *Desert Storm*, the American M-1 tank was capable of seeing and achieving first round hits at ranges in excess of 2,000 meters, day or night – a huge leap in capabilities.

Similar leaps have also occurred in both the sea and air domains. Detection ranges have become much greater, weapons systems have achieved much further reach and precision technologies allow first round kills. When these factors are combined, they enable defenders to prevent access to selected locations and deny attackers the ability to operate freely in large areas. Thus, as many analysts have been noting for the past several years, a growing number of states are clearly adopting A2/AD strategies and developing the means to enforce them.[3] China's recent declaration of an "air defense identification zone" (ADIZ) over the Senkaku Islands in the East China Sea is a prime example. It has already led to a series of claims and counter-claims by Japan and South Korea, clearly demonstrating that nations in the Asia-Pacific region are actively engaged in such strategies to widen and broaden their zones of control.

The strategic and military implications of this are significant. The strategic focus of the United States is clearly shifting to the Asia-Pacific region, as announced in a series of statements by the Obama administration in 2011.[4] This strategic "rebalancing" is intended to address signs of increasing regional influence – and aspirations – by China. However, other emerging powers, along with autocratic states such as North Korea, are also capable of presenting troubling if smaller challenges.[5]
The military dimension of this strategic shift was signaled by the Pentagon in its 2010 Quadrennial Defense Review when it began describing a new concept of "Air-Sea Battle" (ASB), one heavily

focused, as the name would imply, on air and naval forces. Although this concept is still evolving, ASB clearly seeks to provide regional presence and enhanced joint operational effectiveness in countering A2/AD efforts across a large geographical area.[6]

Conceptually, these goals suggest that in any future regional conflict the ability of air and naval forces to conduct both short and sustained air campaigns will be an essential military capability. This raises two issues: whether air assets can be positioned in a way so they can reach high-value targets, and whether they can penetrate the modern, highly-capable air defenses that they will inevitably encounter.

This report focuses on the second issue: penetration of heavily defended airspace. Over the past three decades, American air forces have impressively conducted both surgical strikes and sustained air campaigns, and have been able to counter adversary IADS. But conditions are never static, and IADS have changed enormously since allied air forces systematically took apart the Iraqi air defense network in both 1991 and 2003. While the major air platforms that the United States would use in future campaigns are much improved, they fundamentally remain unchanged in design since their initial fielding – a date often 10, 20 or even more years in the past. Meanwhile, the opposition they will face has grown enormously more capable, and will continue to do so.

Stealth aircraft have demonstrated that they are a key element of success in such campaigns, but modern advances in both radar and SAMs have steadily eroded their advantage. Meanwhile, although U.S. electronic attack aircraft, such as the EA-6B Prowler, continue to perform key support jamming of enemy acquisition and fire control radar, they have aged considerably. Moreover, their experience over the past decade against less than sophisticated threats has caused some to speculate that American air forces may not be as experienced in high-end campaigns as necessary, and may not have the modern capabilities needed to lower risk and assure success.

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DOUBLE-DIGIT SAMS

The greatest threat to future U.S. air operations, particularly the very demanding "first strike/first night" missions, has been the development of the latest generation of surface-to-air missiles, the so-called double-digit SAMs, along with the radar and other supporting equipment that provide their acquisition and guidance.[7] Andrew Krepinevich, Barry Watts and Robert Work concisely summarized this growing challenge a decade ago:

> While it would be foolhardy to dismiss the potential threat posed by advanced fighters such as the Russian Su-37 Super Flanker, the more worrisome challenge lies in so-called double-digit SAMs such as the Russian S-300PMU-2 Favorit (the export version of the SAM NATO codenamed the SA-10) and S-400 Triumph (codenamed the SA-20). To give a sense of the area-denial potential of these systems, the S-300PMU-2 (or SA-10D) is credited with a maximum range of some 109 nautical miles (nm) (200 kilometers) using the 48N6E2 missile, and the Russians have advertised that, with a new missile, the S-400 will have a reach approaching 400 kilometers. It has also been reported that these SAMs will have capabilities against stealthy aircraft such as the F-117.[8]

When combined with the reach of longer-ranged, precision attack systems of modern land attack missiles, the friendly bases and platforms that launch U.S. attack aircraft are also now themselves at risk. In addition, even as the engagement ranges of these threatening SAMs have increased, the operating radius of the latest stealth aircraft, the F-22 and the F-35, have not kept pace. These aircraft will now be at risk from double-digit SAMs (if detected), oftentimes for nearly half of their mission profile. Some of this threat can be mitigated by extending their operational range with aerial refueling. But airborne tankers are not stealthy and will be clearly visible at greater ranges in the future – which means that refueling must be done further and further from intended targets.

Most modern SAMs are also highly mobile and can be relocated around protected areas in a relatively short amount of time. This makes them much less susceptible to attack by cruise missiles such as the Tomahawk Land Attack Missile (TLAM). Although very effective in the past, TLAMs (and similar missiles launched from various platforms) work best against fixed targets whose location can be loaded into guidance packages. Mobile targets, by contrast, are best attacked by aircraft that can be quickly vectored to new locations as they are determined. No matter how mobile, SAMs and their associated radar at some point have to stop and set up in order to acquire and engage targets. But it is safe to assume that adversaries have developed tactics that re-position these modern SAMs often enough to make the planning of TLAM attacks very difficult.

Furthermore, modern double-digit SAMs are proliferating widely. Several countries make variants of double-digit SAM systems, and the competition in the export market is intense. Moreover, counties that produce or acquire these systems can further optimize them in various ways making them even more capable and deadly. Air planners must therefore assume that the U.S. military will face these systems in areas well beyond the Asia-Pacific region in the years to come.

MULTI-BAND RADAR

While missiles are growing more capable, the radar associated with them – providing target search and acquisition as well as fire control and engagement – are also becoming more effective. Modern threat radar, which are also beginning to proliferate rapidly and widely, are able to operate, often with a single antenna, on numerous bands and frequencies that reduce the advantages of stealth. In addition, they can be widely dispersed and networked tino various firing units. In this environment, a modern ground-based system where power generation can be more easily increased than it can within the confined space of an airborne system has significant advantages.

In her 1999 study of radar and air defenses, Rebecca Grant noted that radar emitting power can be adjusted upward to overcome some of the advantage resulting from the reduced RCS stealth provides.[9] Since a 40 percent reduction in RCS reduces the detection range of a target by 10 percent, attackers gain significant advantages, since reduced detection time leads to reduced reaction time for missile defenses.[10] But additional emitting power becomes a key variable in the radar range equation, just as it was during World War II. The British used chaff (strips of aluminum dispensed by aircraft) to blind and confuse German radar.[11] In response, the Germans simply increased power on their ground radar in order too "burn through" the chaff.

Addressing These Threats: Stealth versus Electronic Warfare

This all suggests that the basic competition, the continuing stroke-counterstroke campaigns inherent in electronic warfare (EW), is continuing and will continue with a recognizable, if not necessarily predictable, pattern. The debate is robust over whether the U.S. military should focus on stealth and reduced RCS, or to counter the new radar and SAM threats with enhanced detection, jamming and ultimately target engagement. Even though stealth has altered the radar game and amplified the need for increasingly more sophisticated radar technologies, it has rendered neither radar nor the IADS dependent on them obsolete.

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STEALTH

The actual value of stealth has been the subject of considerable debate. There are those, particularly in the U.S. Air Force, who believe that in the near future (if not currently) non-stealthy aircraft will simply not be survivable against contemporary air defenses – systems comprised of radar that is shifting to the low end of the frequency spectrum, is capable of rapid multi-band operation, is dispersed and is linked to double-digit SAMs. Stealth advocates point to the downing of the F-117A over Serbia in 1999 as evidence of the need for further enhancements in stealth technology rather than proof of its demise. Simultaneously, stealth critics point to the same incident to indicate the limitations of stealth and the challenges resulting from the need for internal weapons storage. This single combat loss of a F-117A should not be seen as definitive proof for either side. It should, however, be seen as strong evidence that in the era of much more modern radar and much more capable missiles, conducting future air attacks and campaigns will be a very complex undertaking for which there is no single solution.

One recent analysis argued that there has been a "revolution" in detecting aircraft with low RCS, while there have not been commensurate enhancements in stealth. Since the stealth qualities of an aircraft are "time-stamped with whatever date it came out of the factory," this assessment suggests that, "Conventional stealth is vulnerable to low-band detection," and relying solely on new fifth-generation fighters (such as the F-22 and the arriving F-35 series of aircraft) will not be a viable way to address these threats.[12]

Whether this perspective is completely true or not, the evidence regarding the rapidity with which technology can progress and be translated into usable military capability seems to favor the world of computer processing and electronics much more heavily than it does the world of aeronautics – at least for the moment. The prediction of Gordon Moore that the computing power of modern

Defining Electronic Warfare

As it has evolved over time, EW has developed sub-specialties, specialized units, specific technologies and its own detailed definitions and language. As currently defined, EW consists of Electronic Attack (EA) – once known as Electronic Counter-Measures (ECM); Electronic Protection (EP) – once known as Electronic Counter Counter-Measures (ECCM); and Electronic Support (ES). Electronic Support consists of directed efforts by an operational commander to determine information and intelligence that can guide subsequent military operations and contains the specialties of Signals Intelligence, Communications Intelligence and Electronic Intelligence.

processors would double every two years (subsequently reduced by Intel executive David House to 18 months), has essentially held true since Moore articulated it in a paper in 1965 – nearly 50 years ago. While advances in aviation design, particularly in military aircraft, have been impressive over an identical time frame, they have certainly not kept pace with those of the electronics world and are unlikely to do so.

The implications of this disparity are profound. These trends suggest that immensely increased processing power will significantly improve the ability of detectors, such as radar, to switch between differing bands and modes rather quickly and to filter out electronic "noise" using immensely increased processing power. Modern radar, using the increased processing power of today's computers, can almost instantly combine numerous bits of electronic information into a usable picture from what would previously have been a cluttered mosaic.

In addition to the basic performance issues, there is the major issue of cost imposition. As seen regularly in the world of commercial electronics and IT, new product development and production, as well as processing costs, have been steadily decreasing. Meanwhile, in the world of modern aviation, particularly military aviation, costs have been steadily increasing, in some cases significantly so. This trend is already evident causing some smaller militaries around the world to question whether they can afford to acquire modern aircraft.

The history of stealth aircraft shows that development times are long, costs are very difficult to control and the requirements are frequently unstable. The F-22 Raptor, the Air Force's first fifth-generation fighter, was initiated in 1986, the first production models delivered in 2003, and initial operational capability (IOC) achieved in 2005. The number of aircraft initially planned was 750, but this was steadily reduced to the 187 finally produced at a total program cost of $62 billion. The F-35 program was initiated in 1994, is currently planned to be in service with customers in 2019, and will have a total program cost of $392 billion for the currently planned 2,457 aircraft.[13]

This experience with fifth-generation aircraft clearly demonstrates that the development time for stealthy air platforms continues to be long, and has been getting longer. In addition, costs have been high and difficult to control. These problems are perhaps inevitable for weaponry so revolutionary, but cost growth has ultimately caused resistance and controversy in the Congressional appropriations process, which has itself created tremendous pressures to reduce procurement quantities. This is clearly a vicious fiscal circle. But perhaps most significantly, on the technological side it has proven to be very difficult for aircraft designers to adjust designs, develop new material solutions and develop production plans as quickly or as cheaply as their counterparts in the electronics community. In short, it appears that those developing radar and missile counters to stealth advancements have, at least in the present, a significant advantage.

ELECTRONIC WARFARE AND JAMMING

As acquisition and fire control radar have increased in sophistication, and as SAMs have become ever more capable, the risks to aircraft attacking well-defended targets and large target areas have substantially increased. Even with the increasing presence of stealth aircraft, such as the F-35 variants, it is expected that air planners will still desire to have jamming support for attack aircraft.

Most jamming support missions require a wide array of aircraft with differing characteristics and capabilities. Given recent technology trends, and the fielding of ever more capable and agile radar designed to amass large amounts of sensor data and then process it into a clear picture, strike packages are certain to require a mix of aircraft: some stealthy, some non-stealthy, some highly specialized and some unmanned. Enhanced weapons, with greater range and some stealth, will also be needed to increase the probability of reaching targets. Determining acquisition plans that will provide this needed set of options for operational commanders will present a challenge.

In the mid-1990s, both the Air Force and Navy began showing renewed interest in improving their joint jamming capabilities. This occurred for numerous reasons, including the costs of stealth, the lengthening time to develop platforms with stealthy characteristics and their inevitably limited procurement quantities. Operational experience and developmental disappointments suggested to both services that mixes of electronic attack (EA) and electronic protection (EP) were very likely a better investment than a predominant reliance upon stealth.

As the EA-6B airborne jamming platform approached the end of its useful life, a major effort was launched to develop and field a replacement. The time frame was largely driven by the expectation that the EA-6Bs would have to be retired by 2019. Since the F/A-18 had a long history of service with the Navy, and had been significantly upgraded with the development of the F/A-18E/F aircraft in 1999, it was decided to pursue a variant based upon that proven airframe as there was considerable confidence it could fill the modified escort role. The result was the EA-18G Growler equipped with the AN/ALQ-99 jammer. The Growler entered service in 2009 after a relatively short five-year development cycle. In addition, the Growler's total cost of development and procurement was estimated to be less than $12 billion.[14]

Types of Jamming Support

There are basically four types of missions that jamming assets may perform in the emerging strategic environment, particularly one with a greater emphasis on the Asia-Pacific region:

Stand-off: Jamming conducted outside of defended airspace. This is wide-area jamming conducted by a specialized aircraft capable of long missions and long on-station times such as the Air Force's EC-130H Compass Call aircraft.

Modified escort: Jamming conducted inside defended airspace and the coverage of opposition radar, but outside of the range of known surface-to-air missiles. Modified escort systems include the Navy's EA-18G Growler and EA-6B Prowler aircraft.

Penetrating escort: Jamming occurring inside the operational range of known surface-to-air missiles. Penetrating escort is rarely used, and its future viability will depend on the presence of stealthy F-22 and F-35 aircraft equipped with active electronically scanned array (AESA) radars.

Stand-in: Jamming conducted inside the "no escape range" of known surface-to-air missiles. Given the high risk of this mission, it would likely only be performed by recoverable Joint Unmanned Combat Air Systems (J-UCAS) and the Air Force's Miniature Air Launched Decoy Jammer (MALD-J).[15]

The jammer carried on the EA-18G, the AN/ALQ-99, is an aging piece of equipment that has been in the inventory for nearly four decades. During that time period, it has gone through continuous upgrades as it has moved from the analog into the digital age. But any system, particularly an electronic one, reaches the point where upgrades are no longer feasible or cost-effective. Furthermore, the physical operation and location of the AN/ALQ-99 pods externally on the aircraft greatly magnify the platform's RCS. A replacement for the AN/ALQ-99 is now in the works in a program titled the NGJ. This program aims to produce a more reliable jammer than the "-99," which would be capable of jamming across numerous radar bands and frequencies with much greater radiated power while addressing a larger number of targets. A development contract was awarded in mid-2013, but a protest has currently halted work. Once this is resolved, the program of record calls for the production of the NGJ in 2018 with fielding of a mid-band capability in 2020 followed by low-band IOC in 2022 and high-band IOC in 2024.

Although this means a developmental time of over a decade, the projected cost is estimated at a relatively modest $7 billion.[16] In short, the development of the EA-18G and the ultimate development and integration of the NGJ will cost about $20 billion – a significant sum, but less than 5 percent of the costs of procuring the total buy of F-22 and F-35 fifth-generation fighters.

Next Evolutions of Electronic Attack: The Road Ahead

How should we expect the stroke-counterstroke contest in EW to evolve over the next decade or more? Certainly, modern SAMs will continue to proliferate, and countries that manufacture them, such as Russia, are already aggressively marketing these systems. As many have observed,[17] had the United States decided to take direct action against Syria during the spring and summer of this past year, American aircraft would have faced a large number of Russian-provided double-digit SAMs. U.S. planners should also assume that other emerging countries developing advanced military technology industries, such as China and India, will develop such systems for both internal use and export. Again, the Chinese declaration of the expanded ADIZ and the American response with B-52 overflights, suggests that this competition is already underway.

However, future military operations are still likely to need to conduct "first night" operations, which will place a premium on aircraft with stealth capabilities. As demonstrated in the past, the more stealth and the lower the RCS, the less time for detection and reaction by the defending IADS. But the costs of stealth aircraft, as we have seen in the case of the B-2, the F-22 and probably at some point the F-35, will inevitably limit their numbers. This numerical reduction could be offset in the future with unmanned attack aircraft, and unmanned jammers that can conduct the stand-in mission within acceptable risk and costs, in combinations enhancing the value of stealth. Yet IADS will certainly retain a significant cost advantage over stealth.

As detection capabilities improve and proliferate, stealth will become less an end in itself and more a specialized component of an integrated, time-phased effort for conducting air attack using all of the elements of EW. Furthermore, less-stealthy, fourth-generation platforms, such as the F/A-18E/F Super Hornet, will remain a significant part of the U.S. fleet for decades to come. For instance, in its January 2012 *Naval Aviation Vision*, the Navy envisages a future carrier air wing with a significant presence of Super Hornets and EA-18G Growlers out past 2030.[18] This means that for at least the next two decades, EA will require effective jammers that can conduct the modified escort mission. This may also require newer assets with stealthy characteristics, such as the Miniature Air-Launched Decoy-Jammer (MALD-J) and perhaps a jamming version of the Navy's Unmanned Carrier Launched Airborne Surveillance and Strike (UCLASS) aircraft, a program that seems to be expanding in its operational aspirations.[19] In addition, it may be necessary to increase the presence of jamming assets in future carrier wings and in other force package configurations.

NEW GENERATION JAMMERS AND DECOYS

The MALD-J, a possible UCLASS jammer, and active electronically scanned array (AESA) radars – such as the AN/APG-79 currently used with the F/A-18E/F – could significantly tilt the EA mission back in favor of the attacker. Being unmanned, the MALD-J would clutter the threat radar picture with numerous decoys that would have to be carefully analyzed to determine their actual identity, and could draw SAM attacks away from actual attack formations. A UCLASS with a jamming capability could present a similar challenge to threat systems, and would conceivably also be employed in the stand-in mission, well inside the range of both enemy radar and SAM coverage. In the future, fifth-generation stealth aircraft, such as the F-35, equipped with improved AESA radar, might also be able to perform this stand-in mission, using the radar's ability to rapidly scan electronically (without a mechanical radar antenna moving from side-to-side) for target acquisition, tracking and fire control of weapons.

Yet systems such as the MALD-J and the UCLASS-J will not be fielded for several years and perhaps longer than a decade. In the meantime, the F-35 aircraft and the F/A-18E/F will have to conduct the airborne electronic attack mission together, relying on their complementary capabilities and differing operational combat radii. The F-35 will have longer legs than the F/A-18E/F by about 30 percent, an attribute that will allow it to benefit from modified escort jamming while using its own penetration range to significantly degrade enemy IADS. This advantage will open the door for follow-on attacks by the fourth-generation Super Hornets against other high-value targets in numerous target sets with acceptable risks. But the ability to conduct such a coordinated effort, particularly during a sustained air campaign, means that key programmatic steps must be made now to effectively address the daunting threat of modern double-digit SAMs. This will require several commitments: developing and fielding the NGJ, as well as conducting an active upgrade program; fielding the MALD; and procuring a family of UCLASS aircraft that can be used in multiple ways.

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The *Naval Aviation Vision* envisages replacing both the F/A-18E/F and the EA-18G after 2032, meaning that both aircraft will continue to serve a role in fleet operations for another 20 years. The platform that eventually replaces one or both aircraft may be some evolved variant similar to the X-47B Unmanned Combat Air System that has recently been conducting carrier landing and takeoff tests. The X-47B incorporates stealth into its design, meaning any future variant of this airframe would be able to complement the F-35C and presumably could assume other support missions such as EA. With the right munitions, this particular aircraft might find a particularly useful operational niche in the EA mission, providing escort jamming, stand-in jamming and target attack. But in any role, on any airframe, manned or unmanned, aggressively engaging in the electromagnetic competition will remain essential.

Recommendations

Given that the ability of the United States to penetrate defended airspace in an A2/AD environment of the future depends on a mix of EA and EP capabilities and appropriate doctrine, DOD senior leadership should make the following four investment and policy choices:

- **Commit to a doctrinal and investment program that recognizes both EA and EP will be required to successfully penetrate future A2/AD environments.** Stealth will require augmentation with jamming and other EA assets to operate against highly capable IADS. Neither EA nor EP can effectively address this environment alone. SAMs have increasingly greater reach, while U.S. manned air attack assets are not increasing their combat radii at a similar rate. This means that attacking future IADS will require a family of systems, and in some cases a highly integrated (as the GAO has suggested) "system of systems."[20]
- **Create doctrinal and operational integration among the various air components and across the various platform communities.** DOD should further explore EA systems that can serve as an "EA quarterback," with a comprehensive view of the battlespace and with the authority to task assets from all services involved in the mission. Platforms that could potentially fill this role exist, but none has been designated to fill it.
- **Prioritize development of the NGJ and other similar capabilities that emerge.** Advancements in electronics occur far faster and far more inexpensively than advancements on airframes. The actual air platforms that are now available are likely to be the ones in use for the next 40 years. If Moore's Law continues to hold over that time, the electronic and computational architecture will expand and change 20 to 25 times. Therefore, a focus on new electronics, computer processing and IT in general will be far more productive and cost-efficient.
- **Change acquisition policy so that the rapid advancements in electronic systems can be quickly operationalized.** In short, the current acquisition system is poorly designed to capture the rapidity of change described above. In future EA, there may need to be a separate "rapid acquisition system" designed to field systems before they are outdated or, worse, obsolete. This may require relying more heavily on demonstrators and prototypes – but in the past, defense technology suppliers have not embraced this approach because the profit margins are too thin. In short, current industrial policy is inconsistent with the reality of Moore's Law – in the area of EA and many others.

Conclusion

In the July 2012 edition of *Proceedings*, Admiral Jonathan Greenert, the Chief of Naval Operations, published a provocative piece titled "Payloads Over Platforms: Charting a New Course."[21] The basic theme of Greenert's essay was that given the time taken to develop them, and the expense inevitably required, the Navy should "settle" for the development of suitable platforms – "trucks" as they were metaphorically described – and focus its primary attention on the payloads that existing, more modest platforms might carry. As Greenert wrote:

> Payloads offer a more rapid means to improve or integrate new capabilities into a proven platform. In contrast to the 15 to 20 years to design and deliver a new ship or aircraft, a prototype or demonstration weapon, sensor, or unmanned-vehicle payload has been developed, assembled, and installed on an existing platform in as little as a few months.[22]

Although stealth has been a major element of EW since its inception, and will continue to be into the future, it will only be able to maintain the advantages it has provided through continuous, extensive upgrades to the platforms into which it has been incorporated.

Greenert laid out a broad discussion that touched on nearly every category of equipment across all naval communities. But he had some very specific observations about the limits of stealth:

> The rapid expansion of computing power also ushers in new sensors and methods that will make stealth and its advantages increasingly difficult to maintain above and below the water. First, though, military sensors will start to circumvent stealth of surface ships and aircraft through two main mechanisms: operating at lower electromagnetic frequencies than stealth technologies are designed to negate, and detecting the stealth platform from angles or aspects at which the platform has a higher signature.
>
> Those developments do not herald the end of stealth, but they do show the limits of stealth design in getting platforms close enough to use short-range weapons.
>
> Maintaining stealth in the face of new and diverse counterdetection methods would require significantly higher fiscal investments in our next generation of platforms.[23]

This essentially describes the challenge that will exist in EA during the coming years. Although stealth has been a major element of EW since its inception, and will continue to be into the future, it will only be able to maintain the advantages it has provided through continuous, extensive upgrades to the platforms into which it has been incorporated. Retrofitting airframes to provide additional stealth is extremely difficult and very expensive. At the same time, developing counters to the elements of stealth through increasingly sophisticated radar providing detection, tracking, and fire control – largely through updates and inserts to existing systems – will occur continuously and routinely. Anyone who owns a personal computer or cell phone is fully familiar with this trend, as updates arrive with regularity through downloadable applications.

This means, inevitably, that strike platforms will have to be supported with capable, agile and adaptable EA assets. This is what Greenert means about payloads being a necessary alternative to new, more elegant platforms. The NGJ illustrates this point perfectly. Since this jammer is expected to be in service with the fleet for as long as four decades, it will need to continuously grow and adapt so it can continue to address a full spectrum of ever-changing threats across all relevant bands and frequencies. Fielding the NGJ is expected to take less than half the developmental time of the F-35, and entail only 2 percent of the cost. Even when including the costs of its planned platform, the fourth-generation EA-18G, total costs will be only 4 percent of JSF. Even if the NGJ costs twice as much as expected, the costs will still be a fraction of a new stealth platform.

Over 30 years ago John Boyd coined the concept of operating inside an opponent's "OODA" loop, which stands for Observe, Orient, Decide, Act. Under Boyd's concept, in any engagement in any domain, the successful party would nearly always be the one whose OODA loop was shortest, the loop with the smallest radius. Greenert, in his assessment, references the enduring validity of Moore's Law, meaning that enhancements in electronic systems and payloads will, for the time being, outpace those of platforms. Therefore, the payloads must receive greater priority and resourcing since, as Greenert described it, "shifting to modular payloads as the primary source of capability enables us to more rapidly and affordably incorporate new technology."[24] This will require the Defense Department to embrace new ways of operating, new concepts in equipment fielding and a significantly new approach to acquisition. The electronic attack mission would clearly benefit from such thinking.

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ENDNOTES

1. In a paper in 1965, Gordon Moore, the co-founder and Chairman Emeritus of Intel Corporation, postulated what has ever since been known as "Moore's Law." According to Moore's Law, the number of transistors on integrated circuitry doubles about every two years. The electronics and semi-conductor businesses have seen this observation hold its validity for many years with processing speed, memory capacity and digitization expanding at exponential rates. No other industry has matched this rate of advance. See P.W. Singer, *Wired for War: The Robotics Revolution and Conflict in the Twenty-first Century* (New York: Penguin Books, 2009), 98.

2. See, for example, Barry D. Watts, "The Evolution of Precision Strike" (Center for Strategic and Budgetary Assessments, 2013); and David Woods, "American Drones Ignite New Arms Race From Gaza To Iran To China," *Huffington Post*, November 27, 2012.

3. This issue is well described, and perhaps originally articulated, in Andrew Krepinevich, Barry Watts and Robert Work, "Meeting the Anti-Access and Area Denial Challenge" (Center for Strategic and Budgetary Assessments, 2003).

4. Congressional Research Service, *Pivot to the Pacific? The Obama Administration's 'Rebalancing' Toward Asia*, R42448 (March 12, 2012).

5. For an excellent assessment of the evident Chinese strategy, see Robert D. Kaplan, "The Geography of Chinese Power: How Far Can Beijing Reach on Land and Sea," *Foreign Affairs*, May/June 2010. Kaplan's assessment also includes an assessment of Chinese concerns about North Korean behavior, which are not dissimilar from American concerns. In addition, visits to China over the past decade by senior American military officers has led them to believe that Kaplan's analysis is largely correct. Author interviews and observations.

6. For a thorough and concise discussion of this strategic pivot, see Congressional Research Service, "Pivot to the Pacific?"

7. The phrase "double-digit" comes from the NATO designation of older Soviet designed equipment. Early SAMs, as identified, were designated by NATO as SA-1 and later SA-2 or SA-3, and were used very effectively by the North Vietnamese during the Vietnam War and the Egyptians and Syrians in the Middle Eastern wars. Current SAMs, such as the SA-10, have been designated with two digits, hence the "double-digit" description.

8. See Krepinevich, Watts and Work, "Meeting the Anti-Access and Area Denial Challenge," 13-14. Although there have been some designation changes for double-digit SAMs, those shown in the quotation are those used in the 2003 CSBA report.

9. See Rebecca Grant, *The Radar Game* (Arlington, Virginia: Iris Independent Research, 1999).

10. For a discussion of the fundamental radar range equation, see Ibid., 32-34.

11. Mark Denny, *Blip, Ping, and Buzz: Making Sense of Radar and Sonar* (Baltimore, Maryland: The Johns Hopkins University Press, 2007), 95.

12. Bill Sweetman, "Cash Crunch: Air Forces face smaller fighter fleets and restricted missions for them," *Aviation Week and Space Technology*, November 25, 2013, 41-42. This observation was made by Michael Garcia of the Raytheon Corporation.

13. See Department of Defense, *Selected Acquisition Report (SAR): F-35 Joint Strike Fighter Aircraft (F-35)*, RCS: DD-A&T(Q&A)823-198 (December 31, 2012).

14. For a cost breakdown of the program, see Department of Defense, *Selected Acquisition Report (SAR): EA-18G Growler Aircraft (EA-18G)*, RCS: DD-A&T(Q&A)823-378 (December 31, 2012).

15. See Government Accountability Office, *Airborne Electronic Attack: Achieving Mission Objectives Depends on Overcoming Acquisition Challenges*, GAO 12-175 (March 2010). The mission descriptions are well described and illustrated on page 7, along with the need for a more integrated and coordinated DOD effort at procuring a "system of systems" for EA as opposed to a "family of systems."

16. See Government Accountability Office, *Next Generation Jammer: DoD Should Continue to Assess Potential Duplication and Overlap as Program Moves Forward*, GAO 13-642 (August 2013). Also see Loren Thompson, "Navy Steps Up New Jammer Effort; First New System in 40 Years," *Breaking Defense*, July 26, 2012.

17. See John A. Tirpak, "The Syria Question," *Air Force Magazine* (March 2013), http://www.airforcemag.com/MagazineArchive/Pages/2013/March%20 2013/0313syria.aspx; and Greg Jaffe, "Syrian downing of Turkish jet serves as Warning," *The Washington Post*, June 26, 2012.

18. The Naval Aviation Enterprise, *Naval Aviation Vision* (January 2012), 33.

19. See Dave Majumdar, "Navy Shifts Plans to Acquire a Tougher UCLASS," *USNI News*, November 12, 2013, http://news.usni.org/2013/11/12/navy-shifted-plans-acquire-tougher-uclass.

20. See Government Accountability Office, *Airborne Electronic Attack*.

21. Admiral Jonathan W. Greenert, U.S. Navy, "Payloads over Platforms: Charting a New Course," *Proceedings Magazine* (July 2012), http://www.usni.org/magazines/proceedings/2012-07/payloads-over-platforms-charting-new-course.

22. Ibid.

23. Ibid.

24. Ibid.

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A U.S. Navy Boeing EA-18G Growler of test and evaluation squadron VX-9 Vampires flies over California in August 2008.

(CMDR. IAN C. ANDERSON, USN/U.S. Navy)