

AIR COMMAND AND STAFF COLLEGE

AIR UNIVERSITY

AIR SUPERIORITY AND THE ANTI-ACCESS/AREA-DENIAL ENVIRONMENT IN THE  
ASIA PACIFIC IN 2044



A Research Report Submitted to the Faculty  
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## **Preface**

This paper is in response to the alarming shortcomings of current operational concepts and Department of Defense acquisitions relating to air superiority in an Anti-Access/Area-Denial environment, specifically in the Asia Pacific 30 years in the future. While the leading concepts, the Air-Sea Battle Concept, Joint Operational Access Concept, and Offshore Control, offer operational frameworks to address many of the challenges, none address air superiority at strategic distances. In addition, current and future Department of Defense acquisition programs, namely the Next Generational Tactical Aircraft and Long-Range Strike-Bomber, fail to provide this capability. Therefore, I propose solutions for this challenge. These include adjusting requirements for the sixth-generation fighter to significantly increase its range, modifying the B-2 for the air superiority mission, and adding this mission set to the Long-Range Strike-Bomber program. While all of these possible solutions have numerous advantages and disadvantages, tough choices regarding the future of airpower need to be made soon to reverse current trends.

The research methods used in this paper are mainly descriptive/qualitative, including case study, and limited descriptive/quantitative methods.

## **Abstract**

America's strategic pivot to the Asia Pacific produces significant challenges to the United States. In addition, Anti-Access/Area-Denial (A2/AD) technology advances will challenge US operations in the next 30 years given planned enhancements to current weapons systems and current concepts of operations. Unfortunately, current operational concepts targeting this A2/AD conflict fail to solve all challenges. The US Air Force must achieve localized air superiority in an A2/AD environment to provide strategic effects in the Asia Pacific. These strategic effects include the adequate means of deterrence to protect our allies and international partners and enable sea control that current operational concepts do not provide.

The A2/AD threats in the Asia Pacific and technological advancements have created a new paradigm in the characteristics of air superiority vehicle requirements. Specifically, advances in stealth, sensors, and weapons have rendered speed and maneuver characteristics less necessary in air superiority vehicle design. In addition, requirements for greater unrefueled range have emerged. Therefore, the United States must develop an air superiority vehicle with an unrefueled combat radius of over 2,000 nautical miles carrying 16 air-to-air missiles.

Upgrades to fifth-generation fighter aircraft are unable to fill the air superiority role in an Asia Pacific A2/AD environment based on their inability to meet these new range requirements. The sixth-generation fighter will be unable to fill this role unless proposal requests increase range requirements and minimize mission sets. Upgrading the B-2, including longer-range air-to-air missiles, could provide a near-term solution. However, requirements changes for the Long-Range Strike-Bomber provide a more survivable solution for the air superiority mission.

## **Anti-Access/Area-Denial Air Superiority in 2044**

When Giulio Douhet advocated for the “battleplane” in 1921, his primary discussion regarded weight.<sup>1</sup> Weight compromises revolved around radius of action, speed, armor protection, armament, and fuel load.<sup>2</sup> Design factors for US air superiority vehicles have placed range less important than others. However, as Anti-Access/Area-Denial (A2/AD) capabilities require air superiority at greater distances from bases, shifts in technology will transform the characteristics of air superiority vehicle requirements.

America’s strategic pivot to the Asia Pacific and A2/AD technology pose serious challenges to the United States in 2044. The United States must provide localized air superiority to protect allied metropolitan areas and to enable sea control in the region. A new paradigm will emerge in the characteristics of air superiority vehicle design based on technological advancements and new requirements. To address these challenges, the United States must develop longer-range air superiority vehicles.

### **Strategic Pivot to the Asia Pacific**

America’s strategic pivot to the Asia Pacific produces significant challenges to the US Air Force (AF). In the Pentagon’s latest guidance, President Obama articulates “as we end today’s wars, we will focus on a broader range of challenges and opportunities, including the security and prosperity of the Asia Pacific.”<sup>3</sup> The economic impact of the region alone requires America to ensure stability and free access to the commons, including air and maritime lines of communication. The Congressional Research Service states, “Ninety percent of global trade by volume travels by sea, and 25 percent of that, approximately 50,000 vessels a year, travels through a 1.7-mile-wide sliver of ocean at the Strait of Malacca.”<sup>4</sup> This economic importance,

combined with China's military rise, economic base, and recent assertiveness, produce concerns for America and its allies.

The United States provides an umbrella of security to numerous allies and partners in the region, and has treaties with the Philippines, Japan, South Korea, and Taiwan.<sup>5</sup> Nuclear and conventional non-proliferation, specifically in the Korean peninsula and Japan, are important for America.<sup>6</sup> However, the area is rife with friction. The South China Sea (SCS) is claimed in totality by both China and Taiwan, and overlapping claims exist with the Philippines, Vietnam, Malaysia, and Brunei.<sup>7</sup> This friction has manifested in Chinese action of late, including the establishment of new fishing regulations,<sup>8</sup> the establishment of an East China Sea Air Defense Identification Zone (ADIZ),<sup>9</sup> discussions of a SCS ADIZ,<sup>10</sup> and the first official US rejection of Chinese SCS territorial claims.<sup>11</sup> While the United States regards these areas as international waters under the Law of the Sea Treaty,<sup>12</sup> Chinese claims become more bellicose each month. In addition, the US Navy (USN) has not sailed a carrier through the Taiwan Strait since 1996,<sup>13</sup> accepting a de-facto blockade of the strait. Japan, caught in the middle, announced a bold plan to develop a sixth-generation fighter, leapfrogging fifth-generation aircraft.<sup>14</sup>

Establishing bases is the traditional method to secure strategic areas of interest. The Center for Strategic and Budgetary Assessments (CSBA) states "permanent or long-term forward bases can assure partners and deter adversaries."<sup>15</sup> However, Asia Pacific bases are constrained geographically, physically, and diplomatically. First, most US bases in the region are in the Western Pacific Ocean and relatively distant from potential flashpoints. Alternative basing options lack facilities and infrastructure to accommodate US fighters.<sup>16</sup> Although the United States is increasing infrastructure in the region,<sup>17</sup> a larger effort is required to produce fighter aircraft basing. Next, the CSBA states, "US requests for forward base access now typically

encounter political resistance, either in the form of refusal to allow access to bases, or the granting of access with severe restrictions on their use, especially in the case of strike operations.”<sup>18</sup> Most regional nations, whether diplomatically aligned with America or not, are economically dependent on China. This dependency decreases nations’ willingness to antagonize China during regional issues. Finally, the Joint Operational Access Concept (JOAC) states “a forward base becomes a resource requiring protection and sustainment and can even become a political liability, often by causing friction with the host nation or within the region.”<sup>19</sup> Increasing regional basing, infrastructure, and presence will meet hardship under current fiscal constraints.

### **Anti-Access/Area-Denial Technology**

A2/AD technology advances will challenge US operations in the next 30 years given planned enhancements to current weapons systems and current concepts of operations. Department of Defense (DOD) guidance lists a primary mission of the Armed Forces to “Project Power Despite Anti-Access/Area Denial Challenges.”<sup>20</sup> However, the Secretary of Defense voiced concerns stating “sophisticated adversaries will use asymmetric capabilities, to include electronic and cyber warfare, ballistic and cruise missiles, advanced air defenses, mining, and other methods, to complicate our operational calculus.... *Accordingly, the U.S. military will invest as required to ensure its ability to operate effectively in anti-access and area denial (A2/AD) environments.*”<sup>21</sup> [emphasis in original] Here, A2 affects movement to a theater while AD affects maneuver within a theater.<sup>22</sup> James Holmes argues since the Soviet Union’s collapse, the United States has enjoyed unfettered access to basing across the globe to project power into a theater.<sup>23</sup> This arguably began after World War II (WWII).

The allies prepared nearly two years to position forces for the D-day invasion, and while the allies had little resistance in England, Churchill's biggest fear was German submarines and the battle of the Atlantic.<sup>24</sup> Coalition forces in Desert Storm took nearly six months to move into theater, but they staged without resistance.<sup>25</sup> However, Russia and China enjoy advanced capabilities to deny US movement to and maneuver within a theater. Richard Halloran states, "In perhaps the most remarkable expansion of military power since the US geared up for World War II, China has relied on its surging economy to provide double-digit annual increases in military budgets."<sup>26</sup>

Several current and future threats to US freedom of action and freedom of maneuver exist in a Chinese A2/AD environment. First, the adversary fighter aircraft threat is significant. According to Acting AF Secretary Fanning, Russia's current fighter aircraft, such as the Su-30 and Su-35, and versions exported to China, are more capable than all but US fifth-generation aircraft.<sup>27</sup> Moreover, Russia and China are testing their own fifth-generation fighters, and China has developed the PL-12 missile, assessed to be nearly equal to the US Advanced Medium-Range Air-to-Air Missile (AMRAAM).<sup>28</sup> Analysts believe Russia will export their fifth-generation aircraft on the world market and China will build their stealth fighters in significant numbers.<sup>29</sup>

Beyond fighter aircraft, Russia is exporting advanced Surface-to-Air Missiles (SAMs). The CSBA argues exported SAMs, such as the S-400, are the more worrisome challenge and could deny access out to 250 nautical miles (nm) to all non-stealth platforms.<sup>30</sup> China is also developing numerous asymmetric capabilities to counter US operations. The JOAC states China has developed long-range reconnaissance and surveillance systems to provide targeting

information, kinetic and non-kinetic antisatellite weapons to incapacitate vital US space systems, and cyber-attack capabilities to disrupt US command and control systems.<sup>31</sup>

The most challenging A2/AD threats appear to target US basing. The JOAC contends, “Historically, a key way to mitigate the degrading effects of distance has been to establish forward bases in the anticipated operational area, thereby maintaining some of the capabilities of a home base at a distant location.”<sup>32</sup> Beyond alternative basing, defending current bases appears challenging. The CSBA states, “Prospective adversaries are developing and fielding, or have ready access to, military capabilities that will place US forces operating from large, fixed forward bases, and in the littoral regions, at increasing risk.”<sup>33</sup> Halloran contends Chinese strategists have planned destruction of US basing in the region, disruption of command lines, and the blockade of logistics resupply during a contingency.<sup>34</sup> He argues that pre-emptive Surface-to-Surface Ballistic Missile (SSBM) strikes would be aimed at all US military airfields in South Korea, Japan, and Guam.<sup>35</sup> Analysts contend bases could be vulnerable out to 2,000 nm in the future.<sup>36</sup>

Sea basing appears as vulnerable, and threats include diesel submarines, mines, swarming boats, and autonomous underwater vehicles.<sup>37</sup> However, the largest threat to US carriers is the SSBM. According to Rear Admiral Michael McDevitt, China relies on mobile land-based ballistic missiles that will soon feature terminal guidance systems capable of kill strikes against moving US carriers.<sup>38</sup> The DOD estimates China will soon be able to engage enemies out to 1,000 nm,<sup>39</sup> and Andrew Krepinevich of the CSBA argues China’s current capabilities include engagements within 1,100 nm, and access denial within 1,600 nm in the near future.<sup>40</sup>

## **Operational Concept Deficiencies**

Current operational concepts targeting this A2/AD conflict fail to solve all challenges. While acknowledging the challenges of basing and air superiority, and discussing the need to maneuver directly against objectives at strategic distances, these interrelated concepts do not articulate requirements for new systems. They discuss changing the way we fight, not what we fight with.

The leading operational concepts for future A2/AD conflict are the JOAC and AirSea Battle (ASB) Concepts. These DOD concepts are intertwined to “describe how a future joint force will overcome opposed access challenges.”<sup>41</sup> The JOAC relies on cross-domain synergy,<sup>42</sup> while the ASB Concept networks forces to attack-in-depth.<sup>43</sup> An alternate strategy, Offshore Control, “uses currently available but limited means and restricted ways to enforce a distant blockade on China.”<sup>44</sup> These concepts rely on US bases vulnerable to missile attacks, do not ensure air superiority during the conflict, and suffer from overly optimistic forecasts.<sup>45</sup>

## **Air Superiority**

The United States will require air superiority in an A2/AD environment in the Asia Pacific 30 years in the future. Air superiority is a staple of US military strategy and will continue to be. Air superiority was defined in its current form by General McConnell, USAF Chief of Staff in 1965, in his document entitled “Air Force Doctrine on Air Superiority.”<sup>46</sup> Current US Joint and North Atlantic Treaty Organization (NATO) doctrine,<sup>47</sup> define air superiority as “that degree of dominance in the air battle of one force over another that permits the conduct of operations by the former and its related land, maritime, and air forces at a given time and place without prohibitive interference by the opposing force’s air and missile threats.”<sup>48</sup>

Air superiority has been critical to joint operations success since WWII. Air superiority's value is displayed in the 1943 Army Field Manual 100-20, where it states, "The gaining of air superiority is the first requirement for the success of any major land operation."<sup>49</sup> Many leading Army generals on all sides, such as Field Marshal Montgomery,<sup>50</sup> Field Marshal Rommel,<sup>51</sup> and General Eisenhower agreed.<sup>52</sup> Current military theorist Colonel John Warden argued, "Since the German attack on Poland in 1939, no country has won a war in the face of enemy air superiority, no major offensive has succeeded against an opponent who controlled the air, and no defense has sustained itself against an enemy who had air superiority. Conversely, no state has lost a war while it maintained air superiority, and attainment of air superiority consistently has been a prelude to military victory."<sup>53</sup> While this omits some exceptions, mainly low-intensity conflict and the Vietnam War, it holds true for most major combat operations.

Current US doctrine, Joint Publication 3-01, agrees on air superiority's significance "because it prevents enemy air and missile threats from interfering with operations of friendly air, land, maritime, space, and special operations forces, assuring freedom of action and movement."<sup>54</sup> Air superiority will continue to be vital in the future. Martin van Creveld, among others, has argued on airpower's impending decline and the unnecessary resource allocation for air superiority vehicles.<sup>55</sup> However, this criticism is based on recent low-intensity conflicts, which is an acknowledged limitation of airpower.<sup>56</sup> In addition, USAF success has contributed to air superiority funding cuts. No enemy aircraft has shot down a USAF aircraft since Vietnam, or attacked an American soldier since Korea.<sup>57</sup>

Allied air superiority grew throughout WWII, and the United States has grown accustomed to global air supremacy over the past 25 years. However, with A2/AD weapons systems and geopolitical realities, the United States will be unable to achieve global air

supremacy during a Chinese conflict. Furthermore, this capability is unnecessary in the future A2/AD environment. Instead, the United States should achieve a “tunnel” of localized air superiority.<sup>58</sup> Rather than persist over enemy territory, an air superiority vehicle should provide time sensitive offensive capabilities at range and forward deployed defensive counter air.

### **Air Superiority to Protect our Allies**

George Galdorosi writes, “By creating credible capabilities to defeat A2/AD threats, the United States can enhance stability in the Western Pacific and lower the possibility of escalation by deterring inclinations to challenge the United States or coerce regional allies.”<sup>59</sup> The ASB Concept’s goal to provide a credible deterrence and allow for a non-escalatory response is sound; however, the United States must gain air superiority over allied metropolitan areas to achieve this. Without this objective, any US response to a crisis would prove impotent. This prospect is difficult considering the A2/AD threat imposed by China, the fact that metropolitan areas of Taiwan, Vietnam, South Korea, and the Philippines are within unrefueled range of Chinese fighter aircraft, and metropolitan areas of Brunei and Japan, in addition to most US basing in the region, are within SSBM range.

### **Air Superiority to Enable Sea Control**

Localized air superiority will enable sea control in the Asia Pacific. Assuming command as Chief of Naval Operations in 2011, Admiral Jonathan Greenert issued a set of “Sailing Directions” proclaiming “we own the sea.”<sup>60</sup> The JOAC, CSBA, and sea power trends over the last century disagree. During the interwar years, fleet ships changed from the battleship to the carrier, and the USN relied on naval aviation as the umbrella of protection it sailed under. By the end of WWII, land-based aviation began providing this umbrella. As Galdorosi argues, “The key factor ... was the range of long-range land-based aviation. Carrier aviation could and did conduct

long-range raids, ... But it was long-range land-based bombers and fighters that pushed forward the offensive air envelope under which amphibious forces operated.”<sup>61</sup> Land- and sea-based airpower was complementary to push Japanese forces to their mainland, each unable to accomplish the task alone.

In the Asia Pacific, the lines of communication in the SCS and Taiwan Straits are characterized by maritime choke points and narrow bodies of water, making maritime operations difficult.<sup>62</sup> To control these vulnerable lines of communication, carriers alone incur too high a risk without land-based air superiority preceding them. Just as air superiority will be localized, so will maritime control in an A2/AD environment. The open battle space of the Asia Pacific will require both air and sea control to operate effectively. Finally, aircraft carriers and the continuous improvements required to enable their survivability are hugely expensive.<sup>63</sup> Therefore, air control will be a precursor to sea control in the Asia Pacific.

### **Current Limitations**

Based on the significant threat to land basing, conventional wisdom would argue the USN can provide air superiority in this mostly maritime environment.<sup>64</sup> However, beyond the SAMs and adversary fighters USN aircraft would face, most analysts agree the most pressing concern for the future US carrier fleet is the limited range of its fighter aircraft.<sup>65</sup> Assuming China's carrier engagement capability at 1,000 nm, this distance is beyond the combat radius of USN fighter aircraft.<sup>66</sup> In fact, carrier strike aircraft are optimized to operate between 200 and 500 nm from deck for fleet defense.<sup>67</sup>

Although non-traditional air superiority capabilities are in development, each is severely limited. Space is considered the ultimate high ground, but political and financial constraints will limit its future air superiority capabilities. Cyber is ubiquitous throughout the warfighting

domain but its attack capabilities can be defended. Ground-based directed energy can be defeated through its reliance on targeting mechanisms. Therefore, until future developments lead to cyber-based, space-based, or directed energy air superiority weapons, air superiority vehicles and SAMs are the most effective ways to achieve air superiority and render any air, land, or maritime target at risk.

### **Air Superiority Vehicle Characteristics**

A new paradigm has emerged in air superiority vehicle requirements based on technological advancements and the A2/AD environment in the Asia Pacific. Richard Hallion in *Airpower Journal* argued, “Aircraft acquisition is inextricably caught up in the interplay and tension between doctrine and operational thought (the requirement pull) on one hand and technology (the technology push) on the other.”<sup>68</sup> These forces played a significant role in air superiority vehicle design following WWII. First, air-to-air fighter aircraft originally based their advantage on speed and maneuverability. Two aeronautical breakthroughs occurred during the mid-twentieth century to propel the transformation in speed: the turbojet engine and supersonic aerodynamics.<sup>69</sup> During the six years of WWII, fighter aircraft top speed rose from 350 to 550 miles per hour (mph), but the following decade witnessed a threefold leap to 1,500 mph.<sup>70</sup> Then, propulsion advances coupled with electronic flight controls, refined aerodynamics, and material technologies enabled the second advantage, maneuverability.<sup>71</sup> Another pair of transformational changes to air superiority vehicle design occurred in the 1970s and 1980s. Computer technology enabled unprecedented progression in sensors and sensor fusion,<sup>72</sup> while advanced computing and composite structures led to stealth technology.<sup>73</sup> Simultaneously, air-to-air missiles utilized these technologies to extend engagement ranges on the battlefield.<sup>74</sup>

The transformational technologies in stealth, sensors, and weapons will change air superiority vehicle characteristics and render speed and maneuverability less essential in air-to-air engagements. In fact, this trend has begun. Since the dramatic speed increase to Mach 2.0, the top speed of fighter aircraft from the second- to fifth-generation has remained largely unchanged.<sup>75</sup> The top speed of US fifth-generation fighters is actually lower than some previous generations. The advent of fourth-generation fighter aircraft in the early 1970s, using lessons from Vietnam, replaced speed with maneuverability as the primary design parameter. Yet the load limits of fighter aircraft have remained at approximately nine g-forces since the F-15 first flew in 1972. Only major increases in stealth and avionics defined the leap from fourth- to fifth-generations.<sup>76</sup> Overall, stealth, sensors, and weapons advances have increased engagement ranges while rendering defenses based on speed and maneuver less effective.

The A2/AD threat and the Asia Pacific pivot have added additional requirements for an air superiority vehicle. Air superiority vehicles must have larger unrefueled range, and this should be a major part of the concept of operations for deterrence in the Asia Pacific. However, larger unrefueled range is not required for all theaters and should not change all vehicle requirements of the future. Therefore, advances in stealth, sensors, and weapons, combined with requirements for greater unrefueled range, and unnecessary speed and maneuver characteristics will propel the United States in a paradigm-shifting view of air superiority vehicle design.

### **Fifth-Generation Fighters**

The United States must develop numerous technologies to support air superiority in an A2/AD environment at greater distances from bases. However, upgrades to fifth-generation fighter aircraft, F-22s and F-35s, are unable to fill this role based on the difficulty to increase their range. The F-22 claims a combat radius of 800 nm with external fuel tanks.<sup>77</sup> These

external tanks increase the aircraft's fuel load from 18,000 pounds (lbs) to 26,000 lbs at the expense of decreased survivability based on increased radar cross section (RCS).<sup>78</sup>

Assuming the vulnerability of US runways in the region, combined with diplomatic challenges in accessing others, F-22s will be unable to fly these distances alone. Yet tanker support is limited based on tanker survivability with the threat. Current Chinese SAM threats extend to 400 km,<sup>79</sup> and Chinese naval assets may extend those ranges further in the future, rendering high RCS platforms extremely vulnerable. Therefore, based on the thin fuel margins flying between the combat zone and tanker aircraft over the Pacific, F-22s would be severely time limited for large force packages to receive fuel. In addition, while the F-22 will be upgraded numerous times in the future, it is limited by its fixed fuselage size. This limits enhancements to its range, and characteristics like power generation and internal volume could limit its ability to harness revolutionary advancements in directed energy (DE) weapons. Finally, F-22s carry six AMRAAMs each, but internal carriage allows no room for larger-sized missile upgrades in the future. The aircraft's sensors may continue to be limited by the missile range, unless technology allows for substantially higher-performance missiles at a smaller size.

The F-35C, the Navy's fifth-generation fighter, with a combat radius of 600 nm using internal fuel,<sup>80</sup> is in essentially the same range predicament. Assuming US carriers must stay outside 1,000 nm from an adversary's coast due to the A2/AD threat, the F-35C is unable to reach the battle space without refueling. While refueling from F-18s is possible, F-18s are vulnerable to enemy fighters and SAMs, limiting their proximity to shore. Also, the F-35C was not designed as an air superiority platform. It carries only two AMRAAMs, severely limiting its usefulness in an air superiority battle.<sup>81</sup> While plans exist for 20 F-35Cs per carrier,<sup>82</sup> the number of sorties generated per day would most likely be 20.<sup>83</sup> Combined, this provides only four

aircraft with eight total AMRAAMs on station, for only ten hours per day, while operating the carrier deck over 14 hours.<sup>84</sup>

### **Sixth-Generation Fighter Requirements**

Current requirements for the sixth-generation fighter will be unable to fill the air superiority role in an A2/AD environment in the Asia Pacific. According to the Capabilities Request for Information (CRFI) for the Next Generation Tactical Aircraft (Next Gen TACAIR), “It must be able to operate in the anti-access/area-denial environment that will exist in the 2030-2050 timeframe.”<sup>85</sup> The CRFI specifies the need for enhancements in reach,<sup>86</sup> and John Tirpak, executive editor for *Air Force Magazine* stated the sixth-generation fighter’s “engines will likely be retunable in-flight for efficient supersonic cruise or subsonic loitering.”<sup>87</sup> However, while the CRFI articulates the requirement in relation to an A2/AD environment, there has been no specific requirement for range.

Without a revolutionary advancement in fuel or engine efficiencies, the only way to achieve the necessary combat radius for this operating environment is by stipulating specific range requirements that will likely increase the size and alter the shape from traditional fighter aircraft. It does not appear that the CRFI, or discussions between USAF and industry leaders, are taking the necessary path to achieve these results. In fact, while the CRFI states the primary mission of the Next Gen TACAIR is Offensive and Defensive Counter Air, it includes additional missions such as Integrated Air and Missile Defense, Close Air Support, Air Interdiction, Electronic Attack, and Intelligence-Surveillance-Reconnaissance.

These additional missions will increase aircraft weight to the detriment of range. As John Boyd argued to lighten the F-15 design, “As for range, there is no faster way to degrade performance on a fighter than to ask for too much.”<sup>88</sup> Although it is not too late to change

requirements for the Next Gen TACAIR program, a drastic mental shift must take place to allow for such a success. Allowing the Next Gen TACAIR to rely on advantages beyond speed and maneuverability to increase lethality and survivability, while upgrading fifth-generation aircraft such as the F-22 and F-35 for more traditional air superiority missions, could provide a complementary solution for air superiority 30 years into the future. However, other options exist in both the near and far term.

### **Air Superiority and the B-2**

In 1997, a Congressionally-mandated National Defense Panel (NDP) stated “we must radically alter the way in which we project power,” by projecting power more rapidly, absent forward access, with smaller units and footprints, and with greater lethality.<sup>89</sup> According to Galdorosi, “this momentum slowed as the attacks of September 11, 2001 dramatically changed the focus of the U.S. military to the exigencies of the global war on terrorism.”<sup>90</sup> Yet the threats and challenges leading to the NDP’s recommendations are still valid nearly 20 years later.

The DOD is not currently developing or investigating long-range air superiority platforms despite the CSBA concluding, “We must, therefore, reduce our dependence on predictable and vulnerable base structure, by exploiting a number of technologies that include longer-range aircraft, unmanned aerial vehicles, and stealthy platforms.”<sup>91</sup> A near-term solution to the long-range air superiority challenge is the B-2.<sup>92</sup> Inherent in the B-2 design is the strategic range missing from current air superiority platforms, up to 6,000 nm unrefueled.<sup>93</sup> Tactical advantages inherent in larger platforms like the B-2 also exist.

While the B-2 could be modified to fire the AMRAAM, it has a large-enough internal weapons bay to include larger weapons, such as an air-to-air version of the Patriot.<sup>94</sup> The Patriot Advanced Capability-2 (PAC-2) boasts a 70 km range from the ground, which would increase

significantly when fired from a high-altitude moving platform.<sup>95</sup> The aircraft could theoretically house 16 weapons at a length of 5.8 meters (m),<sup>96</sup> utilizing a weapons bay capable of a 40,000 lb load,<sup>97</sup> and a history of carrying 6.2 m weapons.<sup>98</sup> Modifying the Patriot for an air-to-air role has been proposed before, including a PAC-3 variant, a 5.2 m missile, on the F-15C air superiority fighter. This compares similarly with current fighter munitions, such as the AGM-88 which is 4.1 m long,<sup>99</sup> and older munitions, such as the AIM-54 which is 3.9 m long.<sup>100</sup> Interested parties for the air-to-air PAC-3 program also included the F-22 and P-8.<sup>101</sup>

Alternative air-to-air weapons enhancements to the B-2 include the Joint Dual-Role Air Dominance Missile (JDRADM) or high-speed air-breathing missile designs.<sup>102</sup> Regardless, a weapons bay allowing for larger missiles with increased kinetic capabilities offset potential deficiencies in the decreased Weapons Employment Zone of the B-2 with its limited maximum speed. Additionally, technology has rendered the lack of maneuverability less effective as an offensive capability in air-to-air combat. Defensively, the B-2's lack of speed and maneuverability is offset through its survivability using stealth and future capabilities, such as DE defensive systems and weapons.

### **Directed Energy in Air Superiority**

DE weapons could revolutionize air superiority, but their development will most likely take incremental steps over the next 30 years. Major General David Scott and Colonel David Robie argued, "At a minimum, directed energy (DE) will be a game changer, but it has the potential to create a revolution in military affairs," and DE "will prove an integral part of our force-application capabilities within 10-20 years."<sup>103</sup> The High Energy Liquid Laser Area Defense System (HELLADS) is one promising development. This program is developing a 150 kilowatt laser for tactical aircraft offensive and defensive systems, with the goal to produce a

laser capable of five kilograms per kilowatt within a three cubic meter volume.<sup>104</sup> While not powerful enough to destroy aircraft, this system could compliment the defensive characteristics of a large platform.

The Next Gen TACAIR CRFI includes requirements for three classes of laser technology by 2030, including a low-powered laser for targeting pod operations, a medium-powered laser for defensive operations, similar to HELLADS, and a high-powered laser for ground and air offensive operations.<sup>105</sup> The CRFI requires these technologies to reach Technology Readiness Level (TRL) four by 2014 and TRL five by 2022.<sup>106</sup> The TRL timeframe for the high-powered laser seems optimistic. To reach a megawatt class laser similar to the Air Borne Laser (ABL) would require a minimum 5,000 kilogram system using the HELLADS ratio, which does not include up scaling difficulties. Patrick Carrick argues these high-powered lasers will not be ready in 30 years for tactical aircraft based on fighter's traditional size and weight.<sup>107</sup> This is most likely true, limiting upgrades to fifth-generation fighter aircraft and carrier-based platforms. However, his prediction may not hold for aircraft the size of the B-2.

Carrick also articulates that pulse-lasers may be the technological leap tactical aircraft require.<sup>108</sup> While little information is available, their peak-power, smaller size, and lower weight look promising for aerial applications. For example, an ABL-type platform with this capability could execute defense of "short, medium, and intercontinental ballistic missiles, thus significantly improving force protection, enabling us to operate from closer bases, and enhancing the positioning of naval forces."<sup>109</sup>

Another avenue for DE research is high-powered microwave weapons. The Counter-electronics High-powered Microwave Advanced Missile Project was a successful effort to defeat adversary electronics with a missile emitting high-powered microwave blasts.<sup>110</sup> Boeing states

this technology could counter passive radars, which specifically target stealth aircraft.<sup>111</sup> This technology could be an equally effective, albeit non-lethal, offensive and defensive system as lasers.

### **Air Superiority and the Long-Range Strike-Bomber**

The most promising program to meet the requirements of a long-range air superiority vehicle in an A2/AD environment, while maintaining a technological edge using updated offensive and defensive systems, lies with the proposed Long-Range Strike-Bomber (LRS-B). Although little information is available, the USAF intends to issue a Request for Proposal (RFP) in the fall of 2014, according to USAF Secretary Deborah Lee.<sup>112</sup> The USAF is hoping to acquire between 80 and 100 of these platforms by the mid-2020s,<sup>113</sup> and while it plans on keeping costs down by utilizing existing technologies, much of the technologies for a long-range air superiority aircraft are realized through existing programs. The LRS-B could utilize F-35 technologies with respect to its Active Electronically Scanned Array radar and other air-to-air sensors, F-22, F-35, B-2, and other platforms advanced stealth technology, and PAC-2, PAC-3, JDRADM, or other missile programs. In addition, it could utilize offensive and defensive laser and microwave DE systems developed under programs previously mentioned. These technologies, while different than the current intent of the LRS-B, could be integrated and fielded within the programs time goals. This vehicle could provide allied air defense, air control in support of sea control, and possibly cruise and ballistic missile defense. Other advantages exist in platforms that execute missions from strategic distances, such as mitigation of force protection issues, but these topics are not addressed in this paper.

This long-range air superiority vehicle would play a significant role in the JOAC. The JOAC presents several general principles to promote the central theme of joint operations in a

future A2/AD environment.<sup>114</sup> The JOAC advises to, “Maneuver directly against key operational objectives from strategic distance.”<sup>115</sup> For example, utilizing a 6,000 nm range the aircraft could depart Darwin, Australia, approximately 2,300 nm from Taiwan and outside of enemy threat capabilities, with hours of on station time carrying 16 long-range air-to-air missiles.

With this capability, it could employ from a variety of basing options,<sup>116</sup> and seize the initiative by deploying and operating on multiple, independent lines of operations.<sup>117</sup> In addition, the JOAC states to, “Maximize surprise through deception, stealth, and ambiguity to complicate enemy targeting.”<sup>118</sup> An air-to-air version of the LRS-B exemplifies this concept by performing an air superiority mission utilizing a traditional bomber-sized stealth aircraft. Yet the most important aspects of this platform would be to, “Exploit advantages in one or more domains to disrupt or destroy enemy anti-access/area-denial capabilities in others,”<sup>119</sup> and “Create pockets or corridors of local domain superiority to penetrate the enemy’s defenses and maintain them as required to accomplish the mission.”<sup>120</sup>

Although a variety of platforms exist to fulfill this requirement, acquisition constraints magnify the urgency for the United States to provide initial guidance. Based on historical acquisition cycles, these decisions must be made soon. For example, the F-22 took 19 years to reach Initial Operational Clearance from the RFP.<sup>121</sup> The B-2 timeline is similar. Since no RFP is currently designed to achieve the requirements necessary for a long-range air superiority vehicle, the United States is likely over 20 years away from fielding such a capability.

### **Recommendations**

The United States should pursue multiple avenues to achieve air superiority in 30 years. First, it must continue to upgrade existing fifth-generation fighters. While it is necessary to provide additional capabilities these aircraft do not provide, the F-22 and F-35 are the backbone

of the US fighter fleet for the foreseeable future. The USAF will operate at reduced fleet size, and the long-range air superiority requirement will not extend globally.

Second, the USAF must develop the capability to quickly project air superiority from strategic distances, specifically a system capable of employing from 2,000 nm with 16 air-to-air missiles, wide-band stealth, and the ability to target SSBM and cruise missiles. This will most likely require a larger platform, which will be difficult to employ from a carrier based on size, range, and weapons payload. Three possible solutions exist. The NEXT GEN TACAIR must incorporate specific range requirements and reduce mission sets to comply. The B-2 could be modified quickly with a suitable weapons load, but its survivability may be limited in the future and it has a small fleet size. The LRS-B is the most likely solution based on range, survivability, and payload.

### **Summary**

The strategic pivot to the Asia Pacific and A2/AD technology pose grave concerns to the United States. The United States must provide localized air superiority to protect allied metropolitan areas and enable sea control in the region. A new paradigm will emerge in the characteristics of air superiority vehicle design based on technological advancements and new requirements. To counter these threats, the United States must develop a long-range air superiority vehicle. This advanced stealth vehicle must achieve a 2,000 nm combat radius while carrying 16 air-to-air missiles to counter aircraft, SSBMs, and cruise missiles. As A2/AD capabilities require air superiority at greater distances from bases, shifts in technology will transform the characteristics of air superiority vehicle requirements. The United States must not allow necessary changes in these requirements to be overshadowed by the dogmas of traditional air superiority vehicle design.

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- <sup>1</sup> Giulio Douhet, *The Command of the Air*, trans. Dino Ferrari (1942; new imprint, Washington, DC: Air Force History and Museums Program, 1998), 117.
- <sup>2</sup> *Ibid.*, 117-119.
- <sup>3</sup> Department of Defense, *Sustaining U.S. Global Leadership: Priorities for 21<sup>st</sup> Century Defense* (Washington, DC: Office of the Secretary of Defense, January 2012).
- <sup>4</sup> Ronald O'Rourke, *China Naval Modernization: Implications for U.S. Navy Capabilities—Background and Issues for Congress* (Washington, DC: Congressional Research Service, 21 March 2013), 94.
- <sup>5</sup> Joseph S. Nye Jr. and David A. Welch, *Understanding Global Conflict and Cooperation: An Introduction to Theory and History*, 9th ed. (Boston, MA: Pearson, 2013), 243-248.
- <sup>6</sup> *Ibid.*, 248-251.
- <sup>7</sup> *Ibid.*, 243.
- <sup>8</sup> Banyan, "Hai-handed," *The Economist*, 13 January 2014, <http://www.economist.com/blogs/banyan/2014/01/south-china-sea> (accessed 16 March 2014).
- <sup>9</sup> Zachary Keck, "China Imposes Restrictions on Air Space Over Senkaku Islands," *The Diplomat*, 23 November 2013, <http://thediplomat.com/2013/11/china-imposes-restrictions-on-air-space-over-senkaku-islands/> (accessed 16 March 2014).
- <sup>10</sup> Zachary Keck, "PLA Officer: China Must Establish South China Sea ADIZ," *The Diplomat*, 22 February 2014, <http://thediplomat.com/2014/02/pla-officer-china-must-establish-south-china-sea-adiz/> (accessed 16 March 2014).
- <sup>11</sup> Parameswaran Ponnudurai, "US Draws Own Line Over South China Sea Dispute," *Radio Free Asia*, 9 February 2014, <http://www.rfa.org/english/commentaries/east-asia-beat/claim-02092014205453.html> (accessed 16 March 2014).
- <sup>12</sup> Joseph S. Nye Jr. and David A. Welch, *Understanding Global Conflict and Cooperation: An Introduction to Theory and History*, 9th ed. (Boston, MA: Pearson, 2013), 243.
- <sup>13</sup> *Ibid.*, 247.
- <sup>14</sup> Bill Gertz, "Lagging in Asian Arms Race, Japan to Develop 6<sup>th</sup> Generation Fighter Jet," *East-Asia-Intel.com*, 28 March 2012, [http://www.east-asia-intel.com/eai/2012/03\\_28/list.asp](http://www.east-asia-intel.com/eai/2012/03_28/list.asp) (accessed 22 January 2014).
- <sup>15</sup> Department of Defense, *Joint Operational Access Concept (JOAC)* (Washington, DC: Office of the Secretary of Defense, 17 January 2012), 7.
- <sup>16</sup> Andrew Krepinevich, Barry Watts, and Robert Work, *Meeting the Anti-Access and Area-Denial Challenge*, CSBA (Washington, DC: Center for Strategic and Budgetary Assessments, 2003), 3.
- <sup>17</sup> Richard Halloran, "AirSea Battle," *AIR FORCE Magazine*, August 2010, 45.
- <sup>18</sup> Andrew Krepinevich, Barry Watts, and Robert Work, *Meeting the Anti-Access and Area-Denial Challenge*, CSBA (Washington, DC: Center for Strategic and Budgetary Assessments, 2003), 2.
- <sup>19</sup> Department of Defense, *Joint Operational Access Concept (JOAC)* (Washington, DC: Office of the Secretary of Defense, 17 January 2012), 7.
- <sup>20</sup> Department of Defense, *Sustaining U.S. Global Leadership: Priorities for 21<sup>st</sup> Century Defense* (Washington, DC: Office of the Secretary of Defense, January 2012), 4.
- <sup>21</sup> *Ibid.*, 4-5.
- <sup>22</sup> Air-Sea Battle Office, *Air-Sea Battle: Service Collaboration to Address Anti-Access & Area Denial Challenges*, staff study, May 2013, 2. The Air-Sea Battle Office defines Anti-Access (A2) as "Action intended to slow deployment of friendly forces into a theater or cause forces to operate from distances farther from the locus of conflict than they would otherwise prefer. A2 affects *movement* [emphasis in original] to a theater" (*ibid.*, 2). The Air-Sea Battle Office defines Area-Denial (AD) as "Action intended to impede friendly operations within areas where an adversary cannot or will not prevent access. AD affects *maneuver within* [emphasis in original] a theater" (*ibid.*, 2).
- <sup>23</sup> James R. Holmes, "U.S. Confronts an Anti-Access World," *The Diplomat*, 9 March 2012, <http://thediplomat.com/2012/03/u-s-confronts-an-anti-access-world/?allpages=yes> (accessed 24 February 2014).
- <sup>24</sup> Rich Muller, "AP 506: The Luftwaffe" (lecture, Air Command and Staff College, Maxwell AFB, AL, 16 January 2014).
- <sup>25</sup> Ronald O'Rourke, *China Naval Modernization: Implications for U.S. Navy Capabilities—Background and Issues for Congress* (Washington, DC: Congressional Research Service, 21 March 2013), 91.
- <sup>26</sup> Richard Halloran, "AirSea Battle," *AIR FORCE Magazine*, August 2010, 46.
- <sup>27</sup> Eric Fanning, acting secretary, US Air Force (address, Air Command and Staff College, Maxwell AFB, AL, 10 December 2013).

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- <sup>28</sup> Maj Clay Bartels, "How the USAF Can Lose the Next War: Losing Air Superiority," Research Report (Maxwell AFB, AL: Air Command and Staff College, 2009), 12.
- <sup>29</sup> US Congresswoman Kay Granger: Representing the 12th District of Texas, "America's Future Air Superiority," <http://kaygranger.house.gov/americas-future-air-superiority> (accessed 25 October 2013).
- <sup>30</sup> Andrew Krepinevich, Barry Watts, and Robert Work, *Meeting the Anti-Access and Area-Denial Challenge*, CSBA (Washington, DC: Center for Strategic and Budgetary Assessments, 2003), 13-14.
- <sup>31</sup> Department of Defense, *Joint Operational Access Concept (JOAC)* (Washington, DC: Office of the Secretary of Defense, 17 January 2012), 9.
- <sup>32</sup> *Ibid.*, 7.
- <sup>33</sup> Andrew Krepinevich, Barry Watts, and Robert Work, *Meeting the Anti-Access and Area-Denial Challenge*, CSBA (Washington, DC: Center for Strategic and Budgetary Assessments, 2003), 3.
- <sup>34</sup> Richard Halloran, "AirSea Battle", *AIR FORCE Magazine*, August 2010, 48.
- <sup>35</sup> *Ibid.*, 48.
- <sup>36</sup> Andrew R. Krepinevich, "Why AirSea Battle?" CSBA: *Center for Strategic and Budgetary Assessments*, 19 February 2010, <http://www.csbaonline.org/publications/2010/02/why-airsea-battle/> (accessed 11 December 2013).
- <sup>37</sup> Andrew Krepinevich, Barry Watts, and Robert Work, *Meeting the Anti-Access and Area-Denial Challenge*, CSBA (Washington, DC: Center for Strategic and Budgetary Assessments, 2003), 52-62.
- <sup>38</sup> Thomas P.M. Barnett, "Big-War Thinking in a Small-War Era," *China Security* 6, no 3 (2010): 5-6.
- <sup>39</sup> Stratfor Analysis, "U.S.: Anticipating Future Threats in the Western Pacific," *Stratfor Global Intelligence*, 15 May 2013, <http://www.stratfor.com/sample/analysis/us-anticipating-future-threats-western-pacific> (accessed 22 January 2014).
- <sup>40</sup> Andrew R. Krepinevich, "Why AirSea Battle?" CSBA: *Center for Strategic and Budgetary Assessments*, 19 February 2010, <http://www.csbaonline.org/publications/2010/02/why-airsea-battle/> (accessed 11 December 2013).
- <sup>41</sup> Department of Defense, *Joint Operational Access Concept (JOAC)* (Washington, DC: Office of the Secretary of Defense, 17 January 2012), 2.
- <sup>42</sup> Department of Defense, *Joint Operational Access Concept (JOAC)* (Washington, DC: Office of the Secretary of Defense, 17 January 2012), 14. The solution offered by the JOAC is "future joint forces will leverage *cross-domain synergy*-the complementary vice merely additive employment of capabilities in different domains such that each enhances the effectiveness and compensates for the vulnerabilities of the others" [emphasis in original] (*ibid.*, 14).
- <sup>43</sup> Air-Sea Battle Office, *Air-Sea Battle: Service Collaboration to Address Anti-Access & Area Denial Challenges*, staff study, May 2013, 4. The ASB Concept's solution is "to develop networked, integrated forces capable of attack-in-depth to disrupt, destroy and defeat adversary forces" (*ibid.*, 4).
- <sup>44</sup> T.X. Hammes, "Offshore Control: A Proposed Strategy for an Unlikely Conflict," *Strategic Forum*, no. 278 (June 2012): 4. Offshore Control "uses currently available but limited means and restricted ways to enforce a distant blockade on China. It establishes a set of concentric rings that *denies* China the use of the sea inside the first island chain, *defends* the sea and air space of the first island chain, and *dominates* the air and maritime space outside the island chain. No operations would penetrate Chinese airspace. Prohibiting penetration is intended to reduce the possibility of nuclear escalation and to make war termination easier" [emphasis in original] (*ibid.*, 4).
- <sup>45</sup> Steven P. Schnaars, *Megamistakes: Forecasting and the Myth of Rapid Technological Change* (New York: The Free Press, 1989), 47-48.
- <sup>46</sup> Grant T. Hammond, *The Mind of War: John Boyd and American Security* (Washington, DC: Smithsonian Institution, 2001), 72-73.
- <sup>47</sup> AAP-06 Edition 2013, *NATO Glossary of Terms and Definitions (English and French)*, 2013, 2-A-11.
- <sup>48</sup> Joint Publication 3-01, *Countering Air and Missile Threats*, 23 March 2012, I-2.
- <sup>49</sup> Maj Clay Bartels, "How the USAF Can Lose the Next War: Losing Air Superiority," Research Report (Maxwell AFB, AL: Air Command and Staff College, 2009), 3-4.
- <sup>50</sup> Joint Publication 3-01, *Countering Air and Missile Threats*, 23 March 2012, I-1. Field Marshal Bernard Montgomery stated, "If we lose the war in the air, we lose the war and we lose it quickly" (*ibid.*, I-1).
- <sup>51</sup> Richard P. Hallion, "Airpower From the Ground Up," *Air Force Magazine* 83, no. 11 (November 2000), <http://www.airforcemag.com/MagazineArchive/Pages/2000/November%202000/1100airpower.aspx> (accessed 3 April 2014). World War II German Field Marshal Erwin Rommel, the "Desert Fox," in 1942 stated "[At the battle of Alam Halfa] nonstop and very heavy air attacks by the RAF, whose command of the air had been virtually complete, had pinned my army to the ground and rendered any smooth deployment or any advance by time schedule completely impossible. ... We had learned one important lesson during this operation, a lesson which was to affect all subsequent planning and, in fact, our entire future conduct of the war. This was that the possibilities of ground

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action, operational and tactical, become very limited if one's adversary commands the air with a powerful air force and can fly mass raids by heavy bomber formations unconcerned for their own safety. ... Anyone who has to fight, even with the most modern weapons, against an enemy in complete command of the air, fights like a savage against modern European troops, under the same handicaps and with the same chances of success. ... The fact of British air superiority threw to the winds all the tactical rules which we had hitherto applied with such success. In every battle to come, the strength of the Anglo-American air force was to be the deciding factor" (ibid.).

<sup>52</sup> Richard P. Hallion, "Airpower From the Ground Up," *Air Force Magazine* 83, no. 11 (November 2000), <http://www.airforcemag.com/MagazineArchive/Pages/2000/November%202000/1100airpower.aspx> (accessed 3 April 2014). US General Dwight D. Eisenhower, supreme allied commander, in comments made while surveying buildup area at the Normandy bridgehead after Operation Overlord, late June 1944 stated "If I didn't have air supremacy, I wouldn't be here" (ibid.).

<sup>53</sup> Col John A. Warden III, *The Air Campaign: Planning for Combat* (Washington, DC: National Defense University Press, 1988), 10.

<sup>54</sup> Joint Publication 3-01, *Countering Air and Missile Threats*, 23 March 2012, I-2.

<sup>55</sup> Martin van Creveld, "The Rise and Fall of Airpower," in *A History of Air Warfare*, ed. John Andreas Olsen (Washington, DC: Potomac Books, 2010), 351-370.

<sup>56</sup> Colin S. Gray, *Airpower for Strategic Effect* (Maxwell AFB, AL: Air University Press, February 2010), 281.

<sup>57</sup> Robert M. Gates, "United States Air Force Academy Speech: As Delivered by Secretary of Defense Robert M. Gates, Colorado Springs, CO, Friday, March 04, 2011," US Department of Defense, <http://www.defense.gov/speeches/speech.aspx?speechid=1543> (accessed 9 December 2013).

<sup>58</sup> Harry A. Foster (Center for Strategy and Technology), interview by author, 29 October 2013.

<sup>59</sup> George Galdorosi, "The U.S. Air-Sea Battle Concept: A New Strategy for a New Era?" *Asia Pacific Defense Reporter*, September 2013, 42.

<sup>60</sup> James R. Holmes, "U.S. Confronts an Anti-Access World," *The Diplomat*, 9 March 2012, <http://thediplomat.com/2012/03/u-s-confronts-an-anti-access-world/?allpages=yes> (accessed 24 February 2014).

<sup>61</sup> George Galdorosi, "The U.S. Air-Sea Battle Concept: A New Strategy for a New Era?" *Asia Pacific Defense Reporter*, September 2013, 41.

<sup>62</sup> Andrew Krepinevich, Barry Watts, and Robert Work, *Meeting the Anti-Access and Area-Denial Challenge*, CSBA (Washington, DC: Center for Strategic and Budgetary Assessments, 2003), 3.

<sup>63</sup> Ibid., 64.

<sup>64</sup> Maj Bruce A. Beyerly, "Bombers and Carriers: Fighting the 21<sup>st</sup> Century Anti-Access Threat," Research Report (Maxwell AFB, AL: Air Command and Staff College, 2004), 27-28.

<sup>65</sup> Stratfor Analysis, "U.S.: Anticipating Future Threats in the Western Pacific," *Stratfor Global Intelligence*, 15 May 2013, <http://www.stratfor.com/sample/analysis/us-anticipating-future-threats-western-pacific> (accessed 22 January 2014).

<sup>66</sup> Ibid.

<sup>67</sup> Andrew Krepinevich, Barry Watts, and Robert Work, *Meeting the Anti-Access and Area-Denial Challenge*, CSBA (Washington, DC: Center for Strategic and Budgetary Assessments, 2003), 33.

<sup>68</sup> Richard P. Hallion, "A Troubling Past: Air Force Fighter Acquisition since 1945," *Airpower Journal* (Winter 1990), <http://www.airpower.au.af.mil/airchronicles/apj/apj90/win90/1win90.htm> (accessed 10 December 2013).

<sup>69</sup> Richard P. Hallion, "Air and Space Power: Climbing and Accelerating," in *A History of Air Warfare*, ed. John Andreas Olsen (Washington, DC: Potomac Books, 2010), 374.

<sup>70</sup> Richard P. Hallion, "A Troubling Past: Air Force Fighter Acquisition since 1945," *Airpower Journal* (Winter 1990), <http://www.airpower.au.af.mil/airchronicles/apj/apj90/win90/1win90.htm> (accessed 10 December 2013).

<sup>71</sup> Ibid.

<sup>72</sup> Ibid.

<sup>73</sup> Ibid.

<sup>74</sup> Ibid.

<sup>75</sup> Ibid.

<sup>76</sup> Ibid.

<sup>77</sup> Lockheed Martin, "F-22 Raptor Specifications," <http://www.lockheedmartin.com/us/products/f22/f-22-specifications.html> (accessed 16 March 2014).

<sup>78</sup> Ibid.

<sup>79</sup> Andrew Krepinevich, Barry Watts, and Robert Work, *Meeting the Anti-Access and Area-Denial Challenge*, CSBA (Washington, DC: Center for Strategic and Budgetary Assessments, 2003), 13-14.

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<sup>80</sup> Lockheed Martin, "F-35C Carrier Variant," <http://www.lockheedmartin.com/us/products/f35/f-35c-carrier-variant.html> (accessed 16 March 2014).

<sup>81</sup> Ibid.

<sup>82</sup> David Barno, Nora Bensahel, and M. Thomas Davis, *The Carrier Air Wing of the Future*, White Paper (Washington, DC: Center for a New American Security, February 2014), 13.

<sup>83</sup> Rebecca Grant, "The Carrier Myth," *Air Force Magazine* 82, no. 3 (March 1999), <http://www.airforcemag.com/MagazineArchive/Pages/1999/March%201999/0399carrier.aspx> (accessed 28 March 2014). Over the 43 days of the Desert Storm air campaign, the F/A-18s averaged only 1.28 sorties per aircraft per day. This equates to approximately 20 sorties per day given 20 aircraft on the carrier with a generous mission capable rate of 0.8 (ibid.).

<sup>84</sup> Based on the carrier operating 1,000 nm from shore, a generous cruise speed of 500 nm per hour, the F-35s would be two hours enroute each way between the carrier and the coast. Allowing for buddy-refueling up to the current SAM threat ring for non-stealth platforms, such as the F-18, this allows for a possible two hour on station time in optimum conditions.

<sup>85</sup> US Air Force, "Next Generation Tactical Aircraft (Next Gen TACAIR) Material Technology Concepts Search," *Federal Business Opportunities*, 3 November 2010. [https://www.fbo.gov/index?s=opportunity&mode=form&id=782e30c9c983f85e7952c2adc426b189&tab=core&\\_cvi=1](https://www.fbo.gov/index?s=opportunity&mode=form&id=782e30c9c983f85e7952c2adc426b189&tab=core&_cvi=1) (accessed 9 December 2013).

<sup>86</sup> Ibid.

<sup>87</sup> John A. Tirpak, "The Sixth Generation Fighter," *Air Force Magazine* 92, no. 10 (October 2009), <http://www.airforcemag.com/MagazineArchive/Pages/2009/October%202009/1009fighter.aspx> (accessed 10 December 2013).

<sup>88</sup> Robert Coram, *Boyd: the Fighter Pilot who Changed the Art of War* (New York: Back Bay Books, 2002), 227.

<sup>89</sup> National Defense Panel, *Transforming Defense: National Security in the 21<sup>st</sup> Century*, Arlington, VA: National Defense Panel, December 1997, 33.

<sup>90</sup> George Galdorosi, "The U.S. Air-Sea Battle Concept: A New Strategy for a New Era?" *Asia Pacific Defense Reporter*, September 2013, 42.

<sup>91</sup> Andrew Krepinevich, Barry Watts, and Robert Work, *Meeting the Anti-Access and Area-Denial Challenge*, CSBA (Washington, DC: Center for Strategic and Budgetary Assessments, 2003), ii.

<sup>92</sup> Harry A. Foster (Center for Strategy and Technology), interview by author, 29 October 2013.

<sup>93</sup> Northrop Grumman, "B-2 Spirit Bomber," <http://www.northropgrumman.com/capabilities/b2spiritbomber/pages/default.aspx> (accessed 19 March 2014).

<sup>94</sup> Harry A. Foster (Center for Strategy and Technology), interview by author, 29 October 2013.

<sup>95</sup> Army Recognition, "Patriot MIM-104 surface-to-air defense missile system," [http://www.armyrecognition.com/united\\_states\\_american\\_missile\\_system\\_vehicle\\_uk/patriot\\_mim-104\\_surface-to-air\\_defense\\_missile\\_data\\_sheet\\_specifications\\_information\\_description.html](http://www.armyrecognition.com/united_states_american_missile_system_vehicle_uk/patriot_mim-104_surface-to-air_defense_missile_data_sheet_specifications_information_description.html) (accessed 24 February 2014).

<sup>96</sup> Ibid.

<sup>97</sup> Northrop Grumman, "B-2 Spirit Bomber," <http://www.northropgrumman.com/capabilities/b2spiritbomber/pages/default.aspx> (accessed 19 March 2014).

<sup>98</sup> David Cenciotti, "Boeing has successfully improved its 30,000-lb Massive Ordnance Penetrator bomb," *The Aviationist* (15 January 2013), <http://theaviationist.com/2013/01/15/improved-mop/> (accessed 19 March 2014).

<sup>99</sup> Stephen Trimble, "Lockheed proposes funding plan for air-launched Patriot missile," *Flight Global* (7 April 2009), <http://www.flightglobal.com/news/articles/lockheed-proposes-funding-plan-for-air-launched-patriot-324842/> (accessed 24 February 2013).

<sup>100</sup> America's Navy, "AIM-54 Phoenix Missile," [http://www.navy.mil/navydata/fact\\_display.asp?cid=2200&tid=700&ct=2](http://www.navy.mil/navydata/fact_display.asp?cid=2200&tid=700&ct=2) (accessed 3 April 2014).

<sup>101</sup> Stephen Trimble, "Lockheed proposes funding plan for air-launched Patriot missile," *Flight Global* (7 April 2009), <http://www.flightglobal.com/news/articles/lockheed-proposes-funding-plan-for-air-launched-patriot-324842/> (accessed 24 February 2013).

<sup>102</sup> *Technology Horizons: A Vision for Air Force Science and Technology 2010-30* (Maxwell AFB, AL: Air University Press, September 2011), 25.

<sup>103</sup> Maj Gen David Scott and Col David Robie, "Directed Energy: A Look to the Future," *Air & Space Power Journal*, Winter 2009, 6.

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<sup>104</sup> Strategic Technology Office, "High Energy Liquid Laser Area Defense System (HELLADS)," *DARPA*, [http://www.darpa.mil/Our\\_Work/STO/Programs/High\\_Energy\\_Liquid\\_Laser\\_Area\\_Defense\\_System\\_\(HELLADS\).aspx](http://www.darpa.mil/Our_Work/STO/Programs/High_Energy_Liquid_Laser_Area_Defense_System_(HELLADS).aspx) (accessed 24 February 2014).

<sup>105</sup> Dave Majumdar, "Air Force Seeks Laser Weapons for Next Generation Fighters," *USNI News*, 20 November 2013, <http://news.usni.org/2013/11/20/air-force-seeks-laser-weapons-next-generation-fighters> (accessed 24 Feb).

<sup>106</sup> US Air Force, "Lasers Systems for Future Air Dominance Platforms," *Federal Business Opportunities*, 15 November 2013, [https://www.fbo.gov/index?s=opportunity&mode=form&id=452e761675d8c05e5599115182696694&tab=core&\\_cview=0](https://www.fbo.gov/index?s=opportunity&mode=form&id=452e761675d8c05e5599115182696694&tab=core&_cview=0) (accessed 24 Feb).

<sup>107</sup> Patrick G. Carrick, acting director, US Air Force Office of Scientific Research (address, Air Command and Staff College, Maxwell AFB, AL, 19 February 2014).

<sup>108</sup> Ibid.

<sup>109</sup> Maj Gen David Scott and Col David Robie, "Directed Energy: A Look to the Future," *Air & Space Power Journal*, Winter 2009, 8.

<sup>110</sup> John Reed, "Boeing's Flying Blackout," *The Complex*, 22 October 2012, [http://complex.foreignpolicy.com/posts/2012/10/22/boeings\\_flying\\_blackout](http://complex.foreignpolicy.com/posts/2012/10/22/boeings_flying_blackout) (accessed 25 February 14).

<sup>111</sup> Robert Johnson, "Boeing Now Has A Missile That Destroys Only Electronics And Leaves All Else Intact," *Business Insider*, 25 October 2012, <http://www.businessinsider.com/beoings-counter-electronics-high-power-microwave-advanced-missile-project-2012-10?0=defense> (accessed 3 April 2014).

<sup>112</sup> Aaron Metha, "James: USAF Expects Long-Range Bomber RFP in Fall," *Defense News*, 26 February 2014, <http://www.defensenews.com/article/20140226/DEFREG02/302260043/James-USAF-Expects-Long-Range-Bomber-RFP-Fall> (accessed 19 March 2014).

<sup>113</sup> Ibid.

<sup>114</sup> Department of Defense, *Joint Operational Access Concept (JOAC)* (Washington, DC: Office of the Secretary of Defense, 17 January 2012), ii.

<sup>115</sup> Ibid., iii.

<sup>116</sup> Ibid., iii.

<sup>117</sup> Ibid., iii.

<sup>118</sup> Ibid., iii.

<sup>119</sup> Ibid., iii.

<sup>120</sup> Ibid., iii.

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