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SEAD FROM THE GROUND UP: SOF'S ROLE IN THE SUPPRESSION OF ENEMY AIR DEFENSES

by

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13. ABSTRACT (maximum 200 words)

The development and proliferation of new Integrated Air Defense System (IADS) components will challenge the U.S. military's ability to achieve air superiority. Since at least 2001, the U.S. military has enjoyed complete freedom of maneuver in the air, resulting in a force that is conditioned to assume it will achieve air supremacy at the very beginning of a conflict. U.S. Special Operations Forces (SOF), in particular, have benefited from air supremacy. Many U.S. military operations include Close Air Support (CAS), Intelligence, Surveillance, and Reconnaissance (ISR), Combat Search and Rescue (CSAR), casualty evacuation (CASEVAC), and rotary-wing supported Quick Reaction Forces (QRF). Without air superiority, access to these capabilities will be degraded. The U.S. military has few options to reliably and efficiently degrade modern IADS. U.S. SOF therefore has the imperative to analyze ways it can support the objective of air superiority through direct and indirect means.

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SEAD FROM THE GROUND UP: SOF'S ROLE IN THE SUPPRESSION OF ENEMY AIR DEFENSES

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ABSTRACT

The development and proliferation of new Integrated Air Defense System (IADS) components will challenge the U.S. military's ability to achieve air superiority. Since at least 2001, the U.S. military has enjoyed complete freedom of maneuver in the air, resulting in a force that is conditioned to assume it will achieve air supremacy at the very beginning of a conflict. U.S. Special Operations Forces (SOF), in particular, have benefited from air supremacy. Many U.S. military operations include Close Air Support (CAS), Intelligence, Surveillance, and Reconnaissance (ISR), Combat Search and Rescue (CSAR), casualty evacuation (CASEVAC), and rotary-wing supported Quick Reaction Forces (QRF). Without air superiority, access to these capabilities will be degraded. The U.S. military has few options to reliably and efficiently degrade modern IADS. U.S. SOF therefore has the imperative to analyze ways it can support the objective of air superiority through direct and indirect means.

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LIST OF ACRONYMS AND ABBREVIATIONS

AAA	Anti-Aircraft Artillery
ASAT	Anti-satellite weapon
C2	Command and Control
CIA	Central intelligence Agency
CLD	Causal Loop Diagram
CFSOCC	Combined Force Special Operations Component Command
COTS	Commercial-off-the-Shelf
IADS	Integrated Air Defense System
IAF	Israeli Air Force
IC	Intelligence Community
IDF	Israeli Defense Force
JFC	Joint Force Commander
NSA	National Security Agency
OCA	Offensive Counter Air
OIF	Operation Iraqi Freedom
RMA	Revolution of Military Affairs
SAM	Surface-to-Air Missile
SAS	Special Air Service
SEAD	Suppression of Enemy Air Defenses
SOF	Special Operations Forces
TTP	Tactics, Techniques, and Procedures
TEL	Transporter Erector Launcher
UAV	Unmanned Aerial Vehicle
UGS	Unattended Ground Sensor
UN	United Nations
USAF	United States Air Force

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I. INTRODUCTION

The United States can expand its thinking about how to achieve air superiority by instructing ground Special Operations Forces (SOF) to support the suppression of enemy air defenses (SEAD) mission, both through direct and indirect means. Air superiority is crucial to the American way of war. While the United States has long been able to assume and plan military campaigns based on air superiority, that assumption may change based on the reemergence of strategic competition with near-peer rivals. Since 1991, Russia and China have been investing heavily in Anti-Access/Area Denial strategies (A2/AD) that emphasize advanced air defense systems. Crucially dangerous is that Russia is also proliferating those systems. To counter that threat, the United States needs options that support our air forces with naval and ground forces. Ground SOF could be particularly helpful in thwarting A2/AD strategies. To decide whether to invest in this course of action, decision makers need relevant information: this thesis analyzes history and current challenges to assess whether and how ground SOF may be better able to support SEAD directly and indirectly. This introduction offers background, in the form of strategic context, a review of the literature, poses the research question, and explains the methodology.

A. BACKGROUND AND LITERATURE REVIEW

1. Strategic Context

In the 2018 National Defense Strategy, the U.S. Department of Defense (DOD) states that the primary challenge to U.S. national security is the reemergence of great power competition.[1] This focus is a significant deviation from the last 17 years, during which U.S. national security goals focused on countering insurgency and terrorism, primarily in the Middle East. The 2018 strategy focuses on maintaining peace by building a more lethal force and on several critical capabilities for modernization, two of which are germane to this research. The first is developing lethal capability in contested environments. More

[1] The Department of Defense. "2018 National Defense Strategy," 2018, 1.

specifically, the U.S. intends to invest in capabilities that allow it to strike power projection platforms inside air and missile defense networks.[2] Second, the United States intends to develop small, dispersed and flexible basing options for power projection purposes.[3] The purpose of both of these modernization efforts is to increase U.S. effectiveness against adversaries employing anti-access strategies.

After the U.S.-led coalition's destruction of Iraqi forces in Kuwait during the first Gulf War, China and Russia begin investing heavily in A2/AD systems specifically designed to counter U.S. military supremacy.[4] In this conflict, the U.S.-led coalition demonstrated vast superiority in ground, air, and Command and Control (C2) capabilities. The advancement of precision-strike and stealth, in particular, revolutionized modern conflict and best exemplifies the ideals of the Revolution of Military Affairs (RMA).[5] Observant adversaries apparently realized that in order to fight and win against the United States, they needed a different approach.[6]

The backbone of anti-access capabilities is ballistic and cruise missiles, advanced integrated air defense systems (IADS), anti-satellite (ASAT) weapons, cyber, and anti-ship/ballistic missile submarines.[7] Russia has made significant investments in A2/AD through investment in surface-to-surface ballistic missiles, air defenses, and submarines.[8] The Russians particularly prioritized air defense whereby they sought layered, integrated and autonomous systems that could strike multiple targets at a distance, for instance, the S-400 air defense system, which entered service in 2007. Russia claims that this system

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[2] The Department of Defense, 2018 National Defense Strategy, 6.

[3] The Department of Defense, 2018 National Defense Strategy, 6.

[4] Stephan Fruhling and Guillaume Lasconjarias, "NATO, A2/AD, and the Kaliningrad Challenge," *Survival* 58, no. 2 (2016), 96.

[5] Fruhling and Lasconjarias, NATO, A2/AD, and the Kaliningrad Challenge, 97.

[6] Fruhling and Lasconjarias, NATO, A2/AD, and the Kaliningrad Challenge, 98.

[7] John Stillion and David T. Orletski, *Airbase Vulnerability to Conventional Cruise-Missile and Ballistic-Missile Attacks* (Santa Monica, CA: RAND, 1999).

[8] Richard Fontaine and Julianne C. Smith, 'Anti-Access/Area Denial Isn't Just for Asia Anymore', Defense One, 2 April 2015, http://www.defenseone. com/ideas/2015/04/anti-accessareadenial-isnt-just-asia-anymore/109108/.

can engage up to 36 aerial targets, to include aircraft and ballistic missiles, from up to 400km.[9] Additionally, the Russians have made advances in ballistic missile technology. In 2015, Russia struck targets in Syria from the Caspian Sea over 1600km away.[10] Russia claims it has another system, the Kh-101, with a range of 4,000km.[11] Russia has also made deliberate attempts to modernize its Kilo-class anti-surface warfare submarines, its Tu-22M Backfire bombers, and its Su-35 fighter- bombers.[12]

Russia is exporting much of this technology abroad. From 2007–2012, under Defense Minister Anatoly Serdyukov, Russia funded advances in defense by exporting defense-related capabilities.[13] In particular, Russia has exported coastal defense systems, advanced air defense systems, helicopters, aircraft, and Kilo-class submarines to customers including Indonesia, China, Vietnam, Iran, and Greece.[14] Russia has also deployed these capabilities to Syria and Crimea.[15] The Club-K anti-ship missile system, which can be concealed in commercial shipping containers and fired from the deck of a cargo ship or train, is another example of advanced technology now available for export markets.[16]

Doctrine and technology drive the balance of offense and defense in military strategy, as scholar Stephen van Evera argues;[17] however, militaries must also be able to

[9]'S-400 Triumph Air Defence Missile System, Russia', Army-technology. com, http://www.army-technology. com/projects/s-400-triumph-airdefence-missile-system/.

[10] Richard Johnson, 'How Russia Fired Missiles at Syria From 1,000 Miles Away', *Washington Post*, 23 October 2015, https://www.washingtonpost.com/graphics/world/ russian-cruise-missile/.

[11] 'All Missiles Great and Small: Russia Seeks Out Every Niche,' *Jane's International Defense Review*, vol. 47, no. 9, 2014.

[12] Fruhling and Lasconjarias, NATO, A2/AD, and the Kaliningrad Challenge, 102.

[13] Katri Pynnöniemi, 'Russia's Defence Reform: Assessing the Real "Serdyukov Heritage,"' Briefing Paper 126 (Helsinki: Finnish Institute of International Affairs, 2013), 7.

[14] Carl Thayer, 'With Russia's Help, Vietnam Adopts A2/AD Strategy', *The Diplomat*, 8 October 2013, http:// thediplomat.com/2013/10/ with-russias-help-vietnam-adoptsa2ad-strategy/.

[15] Darren Boyle, 'Putin Rolls Out the Big Guns', Daily Mail, 12 November 2015, http://www.dailymail.co.uk/ news/article-3316195/Vladimir-Putindeploys-advanced-Growler-antiaircraft-missile-Syria-able-hit-jetsaltitude-90-000-feet-far-away-Tel-Aviv.html.

[16] Lajos F. Szaszdi, 'The Club-K: A Deadly "Pandora's Box" of Cruise Missiles,' *Daily Signal*, 2 August 2011, http://dailysignal. com/2011/08/22/the-club-k-a-deadly%E2%80%9Cpandora%E2%80%99sbox%E2%80%9D-of-cruise-missiles/.

[17] Stephen van Evera, "Offense, Defense, and the Causes of War," *International Security* 22, no. 4 (1998): 5.

adapt their doctrines to changes in enemy doctrine and the ever-quickening pace of technology. Israeli military theorist Meir Finkel argues that flexible and adaptable doctrine allows militaries to better handle surprise.[18] Both China and Russia adapted their doctrine by investing heavily in anti-access strategies that emphasized advanced air defense systems.[19] The effectiveness of these systems, coupled with the fact that Russia is proliferating them, represent a significant challenge to the U.S. military's ability to achieve air superiority against its near-peer competitors and other potential adversaries.

Airpower theorist John Warden argues that the best way to achieve air superiority is by combining air with naval and ground forces.[20] Current U.S. joint doctrine does call for SOF to have a role in the fight for air superiority in the form of sabotage or raids against air defense systems.[21] However, little investment has been made to develop the requisite technology or define specific roles and missions in this area that maximize SOF's strategic utility, as advocated for by strategist Colin Gray.[22]

2. Airpower Theory

Twentieth-century Italian airpower theorist Giulio Douhet argued that one of the most significant advantages of airpower is that it allows a military to go past the lines of enemy defense without having to break through them.[23] However, Douhet did not predict the advantageous advancement and proliferation of modern air defenses through capabilities aimed to attrite and to amplify the time-distance problem associated with air

[18] Meir Finkel, *On Flexibility: Recovery from Technological and Doctrinal Surprise on the Battlefield* (Stanford: Stanford University Press, 2011), 2.

[19] Stephan Fruhling and Guillaume Lasconjarias, "NATO, A2/AD, and the Kaliningrad Challenge," *Survival* 58, no. 2 (2016), 96.

[20] John A. Warden, *The Air Campaign: Planning for Combat* (Washington, DC: National Defense University Press, 1988), 132.

[21] U.S. Department of Defense. "Joint Publication 3-01: Countering air and Missile Threats." 02 May 2018, from http://www.jcs.mil/Portals/36/Documents/Doctrine/pubs/jp3_01_pa.pdf?ver=2018-05-16-175020-290, III-19.a.

[22] Colin S. Gray, *Explorations in Strategy*, Westport Connecticut: Greenwood Press, 1996, 168.

[23] Giulio Douhet, *Command of the Air* (Washington, DC: Coward-McCann Inc., 1942), 251.

combat.[24] Modern air power scholar Joseph Locke characterizes the tactical, operational, and strategic implications of time in terms of the amount of time aircraft can remain over their objectives, sortie generation, and pilot and aircraft production.[25] By affecting the first two of these variables, modern air defense systems increase the difficulty of achieving air superiority.

The modern practice of SEAD has its roots in the Vietnam War;[26] however, much has changed since then. In his study, *The Air Campaign: Planning for Combat*, air power theorist John Warden defines air superiority, the conditions for it, and suggests options to achieve it.[27] Warden argues that air superiority is achieved not only by defeating enemy aircraft in the sky, but also by disrupting logistical infrastructure and supply chains, aircraft on the ground, and air defenses. SEAD expert James Brungess argues that the evolution of SEAD tactics has been driven in part by the sophistication of enemy air defenses.[28] He further argues that SEAD tactics must evolve from a platform-focused and geography-oriented approach to one that is characterized by functionally pooling joint, objective-oriented resources. In light of these arguments, perhaps there are roles and missions for ground SOF that could help air forces overcome the problem of modern air defenses.

3. SOF Roles and Missions

Strategist Colin Gray argues that the use of SOF can offer strategic options to decision makers because SOF can deliver a disproportional effect compared to its cost.[29] He identifies two master claims for the strategic utility of SOF. First, SOF provides

[24] Stephan Fruhling and Guillaume Lasconjarias, “NATO, A2/AD and the Kaliningrad Challenge,” *Survival* 58, no. 2 (2016): 99.

[25] Joseph W. Locke, “Air Superiority at Red Flag: Mass, Technology, and Winning the Next War” (Maxwell Air Force Base, AL: Air University Press, 2009), 4–6.

[26] Dan, Hampton, *The Hunter-Killers: The Extraordinary Story of the First Wild Weasels, the Band of Maverick Aviators Who Flew the Most Dangerous Missions of the Vietnam War* (New York, NY: HarperCollins, 2015), 103.

[27] John A. Warden, *The Air Campaign: Planning for Combat* (Washington, DC: National Defense University Press, 1988), 130.

[28] James R. Brungess, *Setting the Context: Suppression of Enemy Air Defenses and Joint Warfighting in an Uncertain World* (Maxwell Air Force Base, AL: Air University Press, 1994), 72.

[29] Colin S. Gray, *Explorations in Strategy* (Westport CT: Greenwood Press, 1996), 168.

economy of force options, whereby a relatively small force can accomplish disproportionally significant tasks. Second, SOF can expand civilian or military leaders' options during peacetime and wartime. Christopher Lamb goes on to argue that SOF has two general roles: the commando role and the unconventional warfare role.[30] A commando role is a direct approach where SOF uses speed, surprise, and audacity to penetrate and precisely strike an enemy. Conversely, the unconventional warfare role aligns with SOF's indirect approach. In this case, SOF advises, assists, or accompanies and partners with a surrogate force. Lamb and David Tucker argue that SOF has the most strategic utility when it is the supported element functioning in an indirect manner.[31] Finally, defense analyst Hy Rothstein argues that smaller units with less high-level oversight tend to be more effective in the conduct of irregular warfare.[32]

There may be direct and indirect roles for SOF in the suppression of enemy air defenses. Examples like the U.S. intervention in Kosovo in the late 1990s, U.S. OPERATION DESERT STORM in 1991, the Arab-Israeli conflicts of 1967, 1973, and 1982, and the exploits of the Long-Range Desert Group in World War Two may all serve as opportunities to evaluate and refine these roles.

B. RESEARCH QUESTION

How can U.S. ground SOF support the SEAD mission? This thesis examines practical examples of the direct and indirect roles for SOF, with a particular interest in cases where SOF works in conjunction with airpower to have decisive effects.

C. METHODOLOGY

Identifying conditions where SOF offers strategic utility in the conduct of SEAD requires historical exploration. Specific cases where the United States used ground SOF to

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[30] Christopher Lamb, "Perspectives on Emerging SOF Roles and Missions." In Richard H. Shultz & Robert L. Pfaltzgraff (eds), *Special Operations Forces: Roles and Missions in the Aftermath of the Cold War*, 1995, 4.

[31] Christopher J. Lamb & David Tucker, *United States Special Operations Forces* (New York, NY: Columbia University Press, 2007), 177.

[32] Hy S. Rothstein, "Less is more: The Problematic Future of Irregular Warfare in an Era of Collapsing States," *Third World Quarterly* 28, no. 2 (2007): 276.

defeat enemy air defenses are rare because this mission area is relatively new to SOF, and some of the few examples that do exist are classified. The strategy for overcoming the scarcity of cases is to use examples of the United States and others using SOF to conduct missions similar to those in which they would suppress air defenses, examples of SOF working closely with air power, and examples of non-standard approaches to SEAD. This approach allows for testing three claims: 1) that SOF can enhance the lethality and survivability of other SEAD assets; 2) that SOF has a direct role in the suppression of adversary air defenses; and 3) that SOF can support the SEAD mission using an indirect approach. This thesis investigates those three claims by using historical analysis, the detailed study of two cases, and system dynamics modeling.

This thesis explores SOF's SEAD role in seven cases in Chapter II. The first example worthy of examination is the exploits of the U.S. Air Force Wild Weasel pilots during the Vietnam War. This case serves as foundational in understanding the history and principles of SEAD. The next set of cases is from the Arab-Israeli conflicts of 1967, 1969, 1973, and 1982. These wars offer insight into how Israeli SEAD theory evolved against modern air defense threats over time. In particular, this study explores how the Israeli Air Force adapted to mobile air defenses by establishing its own SOF element with the tasks of reconnaissance and direct action. During OPERATION DESERT STORM in 1991, the U.S. military utilized army AH-64 attack helicopters and MH-53 Pave Low helicopters to establish an air corridor inside Iraq. Whereas SEAD is traditionally viewed as a mission for fixed-wing aircraft, this case serves as a lateral look at a non-standard approach to SEAD. American operations in Kosovo in 1999 represent a conflict where cyber warfare, deception, and covert action were either used or planned to be used. Therefore, while not explicitly tied to SEAD, these cases are fertile ground for the exploration of SOF's indirect roles on the modern battlefield.

Chapter III then refines and tests the claims of SOF's direct and indirect roles in SEAD through the detailed study of two cases: the U.S. military's SCUD hunting campaigns in 1991 and 2003, and Israel's OPERATION ORCHARD in 2007. For the first claim, this study compares and contrasts the U.S.-led SCUD hunt during OPERATION DESERT STORM with the U.S.-led SCUD hunt during the invasion of Iraq in 2003. These cases were selected on the basis that they exemplify small SOF elements working in concert with air forces and the military intelligence apparatus to find, fix, and destroy hard-to-find strategic targets. Exploration of the 1991 SCUD hunt could actually be a compelling case in validating SOF's role, as it is an unlikely case to use since many point to the tactical failures of SOF in finding and destroying SCUDS. The U.S. military was much more effective in the destruction of SCUDs in 2003. Thus, a study of how the U.S. evolved its strategy for SCUD-hunting could inform the capabilities SOF should develop and help identify the conditions for success.

Central to the claim of an indirect role for SOF in SEAD is the notion that favorable conditions for air superiority can be achieved before the onset of major combat operations. This concept is unorthodox to contemporary U.S. military planners, so this thesis provides a strong example in Chapter IV. In 2007, Israeli fighter-bomber aircraft struck a nuclear reactor in Syria; this mission was called OPERATION ORCHARD. In this case, the Israelis used a cyberattack to spoof Syrian air defenses, which drastically reduced operational risk, plus the pilots received their mission tasking while in flight on a training mission guaranteeing OPSEC. This operation is especially interesting because it is a modern example where a military successfully set conditions for a strategic air strike through the employment of cyber to suppress enemy air defenses.

Chapter VI concludes this thesis with analysis, favorable conditions, and key recommendations.

Additionally, the Appendix presents an evaluation of SOF's ability to increase the lethality and survivability of a SEAD campaign, through the development of a system dynamics model. System dynamics modeling exposes the relationship between interacting elements by exploring how one party's actions affect the other party's behavior. This dynamic is modeled with a Causal Loop Diagram (CLD). This Appendix models the relationship between a notional SEAD force and a notional IADS. Variables are categorized under lethality, survivability, and targeting effectiveness. After the variables and their respective polarities are mapped, it models them using the Stella System Dynamics modeling software. SOF's ability to increase the effectiveness of a SEAD campaign in the model to explore how SOF can assist in defeating IADS is included.

II. THE ORIGIN AND EVOLUTION OF SEAD

According to U.S. military doctrine, SEAD is a form of Offensive Counter Air (OCA).[33] The purpose of SEAD is to allow a Joint Force Commander (JFC) to achieve his desired degree of air control by destroying or disrupting an IADS.[34] An IADS is an aggregate of the sensors, weapons, Command and Control (C2), communications, intelligence systems, and personnel designed to deny control of the air through ground-based air defense.[35] To defeat such systems, joint planners employ a variety of SEAD assets that can include ballistic missiles, aircraft, naval and ground forces, and SOF. As per JFC priorities, these assets can be individually tailored for SEAD or can be multirole and repurposed to support SEAD requirements.[36] Military scholar James Brungess argues that an effective SEAD campaign will destroy a nation's ability to defend itself from air attack.[37] However, the development and proliferation of new Russian air defense systems greatly complicates the U.S. military's ability to maneuver freely in the skies. Against nations armed with such systems, advancements in SEAD capabilities and Tactics, Techniques, and Procedures (TTP) are a necessary condition for the success of U.S. military strategy/campaigns. Without effective SEAD, the U.S. military will be unable to rely upon real-time Intelligence, Surveillance, and Reconnaissance (ISR), airborne interdiction, responsive support to ground forces via Close Air Support (CAS) and casualty evacuation, and airborne mobility options.

This chapter provides the contextual basis for modern SEAD by first describing its definition, purpose, and principles. Second, it assesses the origins of SEAD through historical analysis of seven chronological cases, beginning with World War II, then

[33] US Department of Defense, "Joint Publication 3-01: Countering Air and Missile Threats," May 2, 2018, ix.

[34] US Department of Defense, ix.

[35] *US Department of Defense*, V–4.

[36] *US Department of Defense*, IV–12.

[37] James R. Brungess, *Setting the Context: Suppression of Enemy Air Defenses and Joint Warfighting in an Uncertain World* (Washington, DC: U.S. Government Printing Office, 1994), 208.

transitions to the formation of modern SEAD that starts with the Vietnam War and continues to this day. Third, this chapter describes specific challenges and opportunities posed by current IADS. Finally, this chapter introduces indirect and direct roles for U.S. SOF in SEAD. Overall, this chapter highlights three main ideas: that SEAD is most effective when the location and disposition of air defense targets are known and communicated in real-time; that SEAD campaigns can be devastating when SEAD assets are employed jointly; and that inclusion of SOF in the SEAD mission area is not only guided by doctrine, but also supported by history.

A. THE PURPOSE AND PRINCIPLES OF SEAD

The purpose of SEAD is to ensure friendly aircraft have freedom of action to accomplish their assigned missions by destroying or disrupting surface-based air defenses.[38] While the general purpose of SEAD has remained constant, the environment has changed significantly. The end of the Cold War brought about a transition period whereby the U.S. perceived any threat of major conflict with a peer adversary as minimal.[39] In turn, the government reduced resources to combat such a threat, and the technology gap between U.S. SEAD capabilities and Russia's IADS began to close.[40] After the U.S.-led coalition's military dominance during OPERATION DESERT STORM, Russia prioritized the development of anti-access strategies characterized by the advancement of long-range and mobile air defense systems.[41] For the U.S. military, the imperative to neutralize these systems would likely become an essential task in any air campaign due to their speed, complexity, and range, limiting U.S. freedom of maneuver.[42] Israeli military scholar Martin van Creveld argues that, in order to overcome these systems,

[38] Thomas Withington, W*ild Weasel Fighter Attack: The Story of the Suppression of Enemy Air Defense* (South Yorkshire, England: Pen & Sword Aviation, 2008), 2.

[39] Brungess, *Setting the Context: Suppression of Enemy Air Defenses and Joint Warfighting in an Uncertain World*, 72.

[40] Brungess, 72.

[41] Brungess, 72.

[42] Brungess, 209.

the U.S. military should adopt a strategy that is joint and relies heavily upon a robust and integrated intelligence apparatus.[43]

This thesis suggests that the optimal SEAD campaign is characterized by a decisive blow at the outset of a conflict that is then supported by persistent identification and neutralization of emerging air defense threats.[44] According to British military scholar Thomas Withington, that decisive blow can be achieved through the successful application of five SEAD principles: surprise, force weight, persistence, intelligence, and deception.[45] Withington argues that, by achieving surprise, SEAD elements will deny an adversary its ability to prepare air defense assets and, therefore, reduce their ability to target and engage SEAD assets before they are destroyed effectively. Withington also asserts that surprise is more reliably achieved when deception is included in the SEAD plan. For example, by feinting, presenting a different target set to enemy air defenses, airborne SEAD assets are more likely to reach their intended targets without getting engaged. The initial engagement against air defenses must be overwhelming, which is why Withington identifies force weight as one of the five principles. He further argues that the weight of the first blow must destroy as much of the IADS as possible. Finally, upon completion of this opening blow, the role of SEAD assets is to provide persistent coverage of the area and suppress emerging air defense threats.[46] Both principles of force weight and persistence depend highly on accurate, near real-time intelligence.[47] Commanders must know everything possible about the IADS before attacking, to include critical vulnerabilities and the specific location and disposition of all the IADS components.[48] In order to provide persistent coverage, the

[43] Martin van Creveld, *Air Power and Maneuver Warfare,* 186.

[44] Withington*, Wild Weasel Fighter Attack: The Story of the Suppression of Enemy Air Defenses,* 3–13.

[45] Withington, 3–13.

[46] Withington, 3–13.

[47] Withington*, Wild Weasel Fighter Attack: The Story of the Suppression of Enemy Air Defenses,* 3–13.

[48] Withington, 3–13.

intelligence picture of a changing air defense battlefield must be continually updated to allow for the suppression of emergent threats.[49]

B. DEVELOPMENT OF SEAD

1. World War II

Radar technology development began during World War I, but the reliance upon radar did not start in earnest until World War II, and SEAD's origins can be traced to a handful of missions during World War II.[50] In response to German advancement in radar technology and hence more effective air defense, the allies developed the capability to jam and destroy radars from the air. An early example of SEAD during World War II was a British capability code-named ABDULLAH, whereby a Hawker-Typhoon fighter aircraft would home in on a German radar and mark it with smoke. Fighter-bombers would then find the smoke and attempt to destroy the radar with bombs or rockets.[51] A second example of early SEAD was the U.S. FERRET program. In 1943, B-24D bombers were locating Japanese radars on the Aleutian Islands and communicating this information to strike aircraft.[52]

SOF played a successful SEAD support role during World War II, though the Allies struggled with German air defenses until late in the war. The first example of a SOF element conducting SEAD was OPERATION BITING. On 5 Dec 1941, 120 troops from the C Company, 2nd Battalion of the British Parachute Regiment, jumped into German territory to dismantle, photograph, and steal essential components of the German *Wurzburg* radar.[53] This successful operation enabled the British to determine that the radar was susceptible to countermeasures. OPERATION BITING is arguably the first example of a

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49 Withington, 3–13.

50 Larry Davis, W*ild Weasel: The SAM Suppression Story,* Vietnam Studies Group 6042 (Carrollton, TX: Squadron/Signal Publications, 1986), 3.

51 Davis, 4.

52 Dan Hampton, *The Hunter-Killers: The Extraordinary Story of the First Wild Weasels, the Band of Maverick Aviators Who Flew the Most Dangerous Missions of the Vietnam War*, 92.

53 Withington, *Wild Weasel Fighter Attack: The Story of the Suppression of Enemy Air Defenses*, 18–19.

joint approach to SEAD.[54] Despite this example, the U.S. Army Air Force loss of a third of its P-47 Thunderbolt aircraft to German flak in OPERATION MARKET GARDEN demonstrated how tough it was to overcome air defenses.[55] After the war, in 1953, the Soviets jumped ahead of the U.S. in Electronic Warfare and Surface to Air Missile (SAM) development with the production of the SA-2 GUIDELINE,[56] demonstrating its ability to influence the global strategic landscape when it shot down Francis Gary Powers' U-2 in 1960 and Rudolph Anderson's U-2 in 1962.[57] During the U.S. war in Vietnam, the SEAD mission became clearly defined, prioritized, and resourced.

2. The U.S. War in Vietnam

The U.S. doctrine to suppress IADS became institutionalized during the Vietnam War as it began to slowly counter the Soviet Union's investment in both airpower and air defenses. When OPERATION ROLLING THUNDER began in 1965, the North Vietnamese air defenses consisted of a few radars, searchlights, and rudimentary Anti-Aircraft Artillery (AAA).[58] However, because it was still recovering from the embarrassment of the Cuban missile crisis, the Soviet Union seemed unwilling to accept another international relations defeat and invested heavily in enhancing the North Vietnamese Army's (NVA) ability to defend itself against U.S. air power.[59] The Soviet Union centered its support to NVA air defenses around the SA-2, which shot down the first American F-4 Phantom, the U.S. premier fighter aircraft at the time, on 24 July 1965.[60] After this engagement, the SA-2 began shooting down aircraft at a rate unacceptable to Americans, which resulted in the repurposing of fighters and bombers to specifically defeat NVA air defenses.[61] However,

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[54] *Withington*, 18–19.

[55] Peter Davies, *F-105 Wild Weasel vs SA-2 "GUIDELINE" SAM: Vietnam 1965–1973* (Oxford, UK: Osprey Publishing, 2011), 4.

[56] Davis, *Wild Weasel: The SAM Suppression Story*, 4.

[57] Davis, 5.

[58] Davis, 8.

[59] Davis, 7.

[60] Davis, 7.

[61] Davis, 7.

this strategy required exchanging multi-million dollar, and often unreplaceable, aircraft for the destruction of SAM installations.[62] In response, the U.S. military assembled an nti-SAM committee chaired by USAF Brigadier General Kenneth Dempster. From the results of this committee, the USAF determined it would organize, train, and equip airmen to pilot specialized aircraft to hunt and kill the SA-2,[63] thus, the WILD WEASEL capability was borne.

With the establishment of the WILD WEASEL mission, the U.S. military began a cat-and-mouse game of capability-balancing with the NVA. With support from the Soviets, by 1966, the NVA had over 2000 AAA pieces and 100 SAM sites in North Vietnam.[64] To counter early U.S. SEAD successes, the NVA tried to fire volleys of missiles without radar guidance in hope for a lucky shot or proximity kill.[65] The NVA also created pre-made SAM sites that allowed them to move SA-2s around more easily; they could move and fully set up an SA-2 in 48 hrs.[66] In response to advancements in U.S. radar jamming technology, the NVA would operate radars on changing frequencies and aim missiles at "clouds" of aircraft jamming.[67] However, SEAD flights not only added cost and complexity for the United States, but they came with opportunity costs. The SEAD mission diverted aircraft that could have been used to strike other targets. Additionally, the United States had to utilize aircraft pylons to carry Electronic Counter Measure (ECM) pods that normally would have carried other ordnance instead.[68] Hungry for any advantage against the SA-2, the United States took an unconventional approach to SEAD, as exemplified by the Central Intelligence Agency's (CIA) OPERATION UNIFIED EFFORT.

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62 Davis, 8.

63 Davis, 8.

64 Dan Hampton, *The Hunter-Killers: The Extraordinary Story of the First Wild Weasels, the Band of Maverick Aviators Who Flew the Most Dangerous Missions of the Vietnam War*, 103.

65 Davies, *F-105 Wild Weasel vs SA-2 "GUIDELINE" SAM: Vietnam 1965–1973*, 43.

66 Davies, 48.

67 Davies, 66.

68 Davies, 72.

That unconventional approach to SEAD saved lives. OPERATION UNIFIED EFFORT was a successful CIA operation to develop countermeasures against the SA-2. The SA-2 guided its missiles, once launched, with a signal that communicated with a beacon responder in the back of the missile body.[69] The purpose of OPERATION UNIFIED EFFORT was to exploit that signal and use it to develop a jamming pod for U.S. aircraft.[70] The operational concept was to use drones to provoke the SA-2 enough to get its operators to fire a missile. Once the missile was fired, the drone collected and communicated data on the signal from the radar to the missile before getting shot down.[71] The success of this operation resulted in the development of the QRC-160A-1 jamming pod. The effectiveness of this pod was such that the USAF required it on all WILD WEASEL aircraft.[72] In 1966, U.S. aircraft were shot down at a rate of 28 out of every 1000 sorties, almost 3%. After the USAF required the QRC-160A-1 be installed on all WILD WEASEL aircraft, that number fell to 16 out of every 1000, close to a 40% reduction in aircraft lost per sortie.[73] While the United States learned a significant amount about SEAD in Vietnam, that knowledge increased due to the Israeli contribution to SEAD doctrine through the lessons learned in the Arab-Israeli conflicts from the late 1960s through the early 1980s.

3. The Arab-Israeli Conflicts

By 1980, the Israeli Defense Force (IDF) had had 20 years to refine its approach to SEAD during sustained combat against Soviet-supported Arab nations. The Six-Day war of 1967, the War of Attrition in 1969, Yom Kippur war of 1973, and OPERATION PEACE FOR GALILLEE in 1982 serve as the foundation of modern Israeli SEAD doctrine.

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[69] Dan Hampton, *The Hunter-Killers: The Extraordinary Story of the First Wild Weasels, the Band of Maverick Aviators Who Flew the Most Dangerous Missions of the Vietnam War*, 173.

[70] Hampton, 173

[71] Hampton, 173.

[72] Hampton, 173.

[73] Hampton, 173.

a. *Six Day War*

While the Six Day War was a highly effective Israeli air campaign, Withington argues that an essential aspect of the conflict was the role of the ground domain for SEAD.[74] In the preemptive Israeli attack on Egypt, the IDF prioritized denying Egypt's ability to defend itself from air attack in the initial phases. In the first few hours, the Israeli Air Force (IAF) destroyed eight Egyptian radar installations.[75] On the second day of the conflict, the Israeli Army and Air Force combined to attack airfields at Mansura, Cairo International Airport, Helwan, Al Minya, Bilbeis, Herghada, Luxor, and Ras Banas in addition to 25 radar sites in the Sinai and west of the Suez Canal.[76] On the third day, the Israeli Army attacked Egyptian SA-2 sites while the IAF provided air support. This combined effort resulted in Israeli air superiority through the destruction of over 400 Egyptian aircraft.[77] The overwhelming success of the IDF in the Six Day War did not go unnoticed by the Soviet Union. In turn, it increased support to the Arab world, which would create new challenges for the Israelis in 1969.

b. *War of Attrition*

The War of Attrition began in 1969 and served as the justification for a marked increase in Soviet investment in Arab air defenses. At the onset of the conflict, the Israelis capitalized on their momentum from the Six Day War and follow-on U.S. investment in the IAF. The Israelis destroyed their first SA-2 installation on 5 September 1969 with an F-4 Phantom purchased from the United States.[78] However, while air power certainly played a role in SEAD, Israeli ground forces mostly won the fight against Egyptian air defenses. The Israelis relied on armored formations to overrun air defense installations,

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[74] Withington, *Wild Weasel Fighter Attack: The Story of the Suppression of Enemy Air Defenses.* 66–69

[75] Withington, 66–69.

[76] Withington, 66–69.

[77] Withington, 66–69.

[78] Withington, 69.

which allowed Israeli air forces to support the ground campaign freely.[79] The Israelis also incorporated special operations into their SEAD campaign. On 26 December 1969, Israeli commandos launched a raid to seize a SA-2 SPOON REST radar located near the Suez Canal.[80] In this operation, IAF aircraft and IDF artillery units struck areas around the radar to distract the Egyptians. Simultaneously, the Israeli commandos infilled via CH-53s, secured the radar site, and loaded vital components into their helicopters. The daring raid provided the Israelis an opportunity to exploit the SA-2 radar and develop technology to jam it.[81] Such was the Israeli advantage that, by the end of 1969, they had destroyed 60 aircraft and all Arab air defenses west of the Suez Canal.[82] In response, the Egyptians purchased from the Soviets more SA-2s and the newly developed SA-3 and SA-6 SAMs.[83] The Egyptians' commitment to air defense was so significant that, by 1970, the Egyptian IADS was considered denser than the one defending Moscow.[84] Egypt's investment in air defense contributed significantly to Israel's troubled start to the Yom Kippur war in 1973.

c. Yom Kippur War

On 6 October 1973, Egypt mounted a surprise attack on Israel. The strategic advantage of surprise, coupled with Egypt's strong air defenses, forced the IDF to rely on its Army to gain some semblance of air superiority. On 8 October 1973, the Israelis launched a mission, named OPERATION DUGMAN, to destroy Egypt's IADS. However, the mobile nature of the SA-6 proved a targeting challenge for the IAF. Such was the Israelis inadequacy in targeting Egypt's IADS that they only destroyed 3 of 31 targeted air defense systems.[85] Within the first three days of the war, the Israelis lost 50 aircraft, 20% of their

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[79] Martin van Creveld, *Air Power and Maneuver Warfare*, 179.

[80] Withington, *Wild Weasel Fighter Attack: The Story of the Suppression of Enemy Air Defenses*, 70.

[81] Withington, 70.

[82] Withington, 69–73.

[83] Withington, 69–73.

[84] Withington, 69–73.

[85] Withington, 69–73.

air force.[86] In response, the IDF adopted a joint approach to SEAD. They used observers on the ground to find SAMs, working in conjunction with IDF artillery.[87] They also used unmanned aerial vehicles (UAV) to draw fire from the SAMs to assist in the targeting challenge, and, finally, they configured helicopters with electronic warfare equipment to jam air defense radars.[88] Encouraged by the early success of these innovations, on 15 October, the IDF launched a massive ground campaign to destroy Egypt's IADS, and Israel's aircraft losses dropped from 38 aircraft for every 3,183 sorties to 4 aircraft for every 2200 sorties.[89] The success of this SEAD campaign quickly provided air corridors for Israeli aircraft to provide CAS, reconnaissance, and interdiction support to the joint campaign. The synergy of ground operations supporting air superiority, which allowed for more freedom of maneuver for air support to ground operations, proved decisive. Within four days, on 19 October 1973, the Israelis were 19 miles from Cairo.[90] They applied a similar strategy in Syria and got within 25 miles of Damascus.[91] By 22 October, Israeli rifles pointed at two of the capitals of the Arab world, which resulted in UN Resolution 338, effectively ending the conflict.[92] Nine years later, the Israeli's would refine the blueprint for joint SEAD during OPERATION PEACE FOR GALILEE.

d. OPERATION PEACE FOR GALILEE

The first of two seminal and masterfully executed examples of SEAD is Israel's OPERATION PEACE FOR GALILEE in 1982. In OPERATION PEACE FOR GALILEE, the Israelis demonstrated their now decades-old experience fighting Soviet air defense systems. The IDF's goal was to halt Arab attacks on the Israel-Lebanon border by establishing a buffer zone. The Israelis accomplished this objective by invading southern

86 Withington, 74–80.

87 Withington, 74–80.

88 Withington, 74–80.

89 Withington, 74–80.

90 Withington, 74–80

91 Withington, 74–80.

92 Withington, 74–80.

Lebanon with ground units supported by helicopters and CAS aircraft.[93] However, there were 125 SAM systems in the Bekaa Valley, presenting a significant obstacle to the Israelis.[94] Furthermore, the Arab system was networked and included the most advanced Soviet systems of the time, such as the SA-2, SA-3, SA-6, SA-7, SA-8, SA-9, and approximately 400 artillery pieces.[95] The IDF's strategy, based on lessons learned from the Yom Kippur war, was to task air forces to work in close coordination with ground forces and SOF to achieve air superiority.[96] For example, the Israelis recognized the importance of finding and fixing SAMs, and therefore tasked UAV's to draw fire to determine where the SAMs were and also to refine their understanding of Arab air defense tactics.[97] They also employed commandos to destroy critical IADS command and control components from the ground with precision surface-to-surface missiles.[98] This missile system, known as ze'ev, was most likely a ground-launched anti-radiation missile that was purposefully built to destroy IADS components.[99] SEAD expert James Brungess argues that Israel succeeded because of their investment in intelligence as demonstrated by their commitment to ensuring intelligence requirements were met before execution.[100] This innovative, disciplined, and joint approach destroyed 17 of 20 air defense targets at the onset of the campaign.[101]

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[93] Withington, 81–87.

[94] Withington, 81–87.

[95] Withington, 81–87.

[96] Martin van Creveld, *Air Power and Maneuver Warfare,* 186.

[97] Withington, *Wild Weasel Fighter Attack: The Story of the Suppression of Enemy Air Defenses,* 81–87.

[98] Withington, 81–87.

[99] Clifford A. Wright, "Israeli War Machine in Lebanon," *Journal of Palestine Studies* 12, no. 2 (1983): 48.

[100] Brungess, *Setting the Context: Suppression of Enemy Air Defenses and Joint Warfighting in an Uncertain World,* 25.

[101] Withington, *Wild Weasel Fighter Attack: The Story of the Suppression of Enemy Air Defenses,* 81–87.

4. OPERATION DESERT STORM

In OPERATION DESERT STORM in 1991, the U.S. military demonstrated how a joint approach to SEAD, applied aggressively at the onset of an air campaign, could be decisive. After Iraq's invasion of Kuwait, the United States had invested heavily in understanding the Iraqi command and air defense situation.[102] The first American attack of OPERATION DESERT STORM was against Iraqi air defenses. Iraq had 1000 AAA pieces and 16000 SAMs.[103] In this opening strike, nine U.S. Army AH-64 APACHE helicopters armed with AGM-114 Hellfire missiles, rockets, and cannons were accompanied by three U.S. Air Force MH-53J PAVE LOW helicopters with the objective to establish an initial air corridor inside Iraq.[104] Their targets were Iraqi IADS components located 435 miles inside the country.[105] The APACHEs were to use then state-of-the-art, night-vision technology and precision weaponry to destroy the IADS components, while the PAVE LOWs provided jamming support against other Iraqi air defenses.[106] Military leaders chose helicopters for this mission because this particular air defense radar was so advanced that U.S. military leadership insisted on visual target-destroyed confirmations[107] and also to counter what turned out to be Iraq's most significant strategic miscalculation of the war.[108] All Iraq's air defenses were oriented to detect and destroy high and medium-altitude aircraft, not low flying helicopters. Twenty minutes after the successful execution of this mission and the opening of an air corridor, USAF F-117 Stealth fighters destroyed 34 targets associated with Iraq's senior command and air defense infrastructure.[109] The air

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[102] Brungess, *Setting the Context: Suppression of Enemy Air Defenses and Joint Warfighting in an Uncertain World*, 39.

[103] *Withington,* Wild Weasel Fighter Attack: The Story of the Suppression of Enemy Air Defenses, 147.

[104] Withington, 150.

[105] Withington, 150.

[106] Withington, 150.

[107] Withington, 150.

[108] Withington, 161.

[109] Withington, 150.

campaign, spring-boarded by a joint special operation to destroy critical IADS components, denied the Iraqi military the ability to defend itself from the air.

5. OPERATION ALLIED FORCE

During OPERATION ALLIED FORCE in 1999, the United States learned important lessons on how air defense strategies could drive an indirect approach to SEAD. At the onset of the operation, the U.S.-led coalition quickly realized that any ground-based intervention in Serbia would require addressing the Serbian IADS.[110] Out of fear of being struck by anti-radiation missiles, the Serbians' general air defense strategy was to shoot SAMs "in the blind" and in mass.[111] The Serbians also used the mountainous Balkan terrain to their advantage by hiding IADS components behind terrain features and underneath forested canopies.[112] The volume of missiles shot in the blind required that allied bombers fly at very high altitude, which degraded bombing accuracy, or at a very low altitude and in the range AAA.[113] The unwillingness of the Serbians to turn their radars on coupled with their terrain advantage presented a significant targeting challenge for SEAD planners. In response, the U.S. military allegedly implanted viruses into the Serbian computers that controlled the IADS, thereby disrupting communications networks and implanting false targeting data.[114] Use of a cyberattack is consistent with the alleged Presidential finding for a covert action to conduct a cyberwar to disrupt targets unreachable from the air.[115] This blending of conventional and unconventional options to defeat air defense systems is consistent with the recommendation of Israeli strategist Martin Van Creveld, who argues that, to defeat modern IADS, planners should include innovative and indirect approaches in their calculus.[116]

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110 Withington, 177.

111 Withington, 182.

112 Withington, 183.

113 Withington, 186.

114 Withington, 187.

115 Gregory L. Vistica, "Cyberwar and Sabotage," *Newsweek,* May 31, 1999, https://www.newsweek.com/cyberwar-and-sabotage-166534.

116 Martin van Creveld, *Air Power and Maneuver Warfare,* 186.

C. THE CHALLENGE OF MODERN IADS

The speed at which modern IADS can acquire targets and shoot them down at extended range presents a strategic problem for joint planners. In many ways, modern IADS are advanced information gathering networks linked to air defense weapons.[117] They have redundant communication nodes and almost instantaneous access to the order-of-battle within their domain.[118] Therefore, SEAD planners must be able to locate and assess IADS components in near-real-time.[119] Critical to this assessment is understanding IADS capabilities, location, and disposition.[120] However, as seen during the Arab-Israeli conflicts, the mobile nature of 1960s technology like the SA-6 presented significant challenges. Military scholar James Brungess questions whether the American Intelligence Community (IC) is up to the task of providing the real-time intelligence requirements that current SEAD campaigns demand.[121] He further argues that the IC's ineptitude in supporting SEAD requirements has significantly constrained American SEAD capability.[122]

Long-range SAMs, in particular, pose a challenge to SEAD elements. Based on unclassified research, the Russian S-400 SAM can simultaneously engage up to 80 targets from over 400 kilometers away.[123] It is also highly mobile and can go from on-the-march to ready-to-engage in five minutes.[124] Such systems will exceed any single SEAD aircraft's ability to survive, let alone establish an air corridor successfully.[125] Brungess

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[117] Brungess, *Setting the Context: Suppression of Enemy Air Defenses and Joint Warfighting in an Uncertain World*, 196.

[118] Withington, *Wild Weasel Fighter Attack: The Story of the Suppression of Enemy Air Defenses*, 168.

[119] Brungess, *Setting the Context: Suppression of Enemy Air Defenses and Joint Warfighting in an Uncertain World*, 169–70.

[120] Brungess, 169–70.

[121] Brungess, 169–70.

[122] Brungess, 169–70.

[123] https://en.wikipedia.org/wiki/S-400_missile_system

[124] https://en.wikipedia.org/wiki/S-400_missile_system

[125] Brungess, *Setting the Context: Suppression of Enemy Air Defenses and Joint Warfighting in an Uncertain World*, 196.

argues that if SEAD elements identify a modern, long-range SAM, its destruction should become an essential task for joint planners.[126] Finally, Brungess argues that successful SEAD campaigns against advanced Russian systems will require a combination of tactics such as jamming, deception, stand-off missiles, and special operations forces.[127]

D. CONTEMPORARY APPROACHES TO SEAD

As exemplified by Israel in 1982 and the U.S.-led coalition in 1991, modern IADS can best be defeated when SEAD campaigns are characterized by a highly capable and integrated intelligence apparatus coupled with simultaneous attacks conducted by combined arms, or, in other words, efficient use of joint teams. In order to acquire the speed and efficiency needed to counter modern air defenses, SEAD forces depend on electronic information gathering and dissemination. Brungess argues that IADS can be suppressed as much by information denial as they can by destruction.[128] Much of the SEAD fight is won by the side that can deny its adversary a targetable solution long enough to effectively target and kill the other. Furthermore, van Creveld emphasizes that, in addition to real-time intelligence, effective SEAD campaigns require synchronized C2 and tight coordination between air and ground assets.[129] These principles are reflected in current U.S. military SEAD doctrine, which emphasizes joint planning, centralized control and decentralized execution, and simultaneous attack with pooled, joint resources.[130]

E. POTENTIAL ROLES FOR U.S. SOF

SOF's contribution to a SEAD campaign should focus on two aspects, lethality and survivability. SOF should increase the lethality of SEAD assets by enhancing their ability to target IADS components and by destroying IADS components as part of a joint campaign. SOF should also increase SEAD asset survivability by degrading IADS

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[126] Brungess, 196.

[127] Brungess, 196.

[128] Brungess, 196.

[129] Martin van Creveld, *Air Power and Maneuver Warfare,* 186.

[130] U.S. Department of Defense, "Joint Publication 3-01: Countering Air and Missile Threats," May 2, 2018, III-1-III–23.

targeting capabilities. SOF is uniquely positioned to provide economy of force options to directly or indirectly contribute to an air campaign. From a direct approach, reconnaissance could contribute to the lethality of the SEAD package by visually identifying the location and disposition of critical IADS components, similar to how the Israelis employed SOF during the Arab-Israeli conflicts. Reconnaissance could also provide real-time battle damage assessments thereby enhancing the SEAD package's understanding of the current disposition of the IADS. Another direct role for SOF is direct action missions to capture IADS components like the British OPERATION BITING in World War II and the Israeli examples during their conflicts with Arab nations. Finally, SOF could increase lethality by destroying IADS components with direct action raids or strikes with surface-to-surface missiles, like the Israelis did during OPERATION PEACE FOR GALILEE. SOF could directly contribute to SEAD package survivability by conducting ground-based jamming proximate to IADS components, thereby reducing the IADS ability to target SEAD assets. Indirectly, SOF could use intelligence operations to characterize up-link and downlink signals between radars and missiles, informing powerful jamming capabilities, similar to OPERATION UNIFIED EFFORT in Vietnam. Ideally, SOF would do so before a conflict to reduce asset loss. SOF should also use the cyber concepts explored in Kosovo in 1999 as a springboard for capability development. Finally, SOF could also use relationships with indigenous forces to locate and potentially sabotage IADS components.

Modern IADS have become a strategic problem for the U.S. military because of their ability to deny air superiority. Examining SEAD's development through a historical lens provides valuable lessons that can inform U.S. SEAD strategy against such threats. The Vietnam War showed that SEAD must evolve from an ad-hoc capability to one that is appropriately organized and resourced. In the Arab-Israeli conflicts, the Israelis learned that IADS must be approached jointly, innovatively, and with a significant investment in intelligence before and during the conflict. Kosovo in 1999 reinforced the importance of effective targeting while introducing new approaches like cyber. While OPERATION DESERT STORM is often thought of as a SEAD campaign won with overwhelming air power, the coalition demonstrated the importance of intelligence preparation and a joint approach that included SOF.

U.S. military SEAD strategy should recognize an IADS as information-gathering networks attached to air defense weapons.[131] Without accurate intelligence that updates in real-time, overwhelming firepower provided by an armada of aircraft and cruise missiles does little. The U.S. military can and likely should pool all available joint resources in order to apply proper force weight at the onset and ensure persistent SEAD coverage throughout the conflict. As such, U.S. SOF is in a position to provide options to disrupt modern IADS. SOF capabilities like reconnaissance, direct action, partner SOF capacity building, and preparation of the environment are SOF-specific capabilities that could contribute to SEAD objectives. Furthermore, U.S. SOF should continue to invest in refining its role in cyber and electronic warfare. The strategic environment demands that SOF stop being only a consumer of air superiority and start contributing to it.

[131] Brungess, *Setting the Context: Suppression of Enemy Air Defenses and Joint Warfighting in an Uncertain World*, 168.

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III. DIRECT ROLES FOR SOF: CASES OF THE U.S.-LED SCUD HUNTS

The previous chapter provided historical examples of how SOF contributed to air superiority by conducting SEAD in both direct and indirect ways. However, it remains to be determined how SOF could accomplish such missions on a 21st century battlefield. This chapter informs the direct roles for SOF in SEAD through a comparative case study of the U.S.-led SCUD hunts of OPERATION DESERT STORM in 1991 and OPERATION IRAQI FREEDOM (OIF) in 2003. While SOF hunting SCUDs is not the same as SOF hunting air defenses, there are similarities. Specifically, SCUDs and long-range air defenses are both strategic, mobile targets that require joint, synchronized, and innovative solutions.

This chapter begins with a description of the background, the concept of employment, and the results of the U.S.-led SCUD hunt of OPERATION DESERT STORM. What follows is a similar description of the U.S.-led SCUD hunt of OIF. Subsequent analysis and comparison of both operations will help inform what lessons SOF planners should take from these operations reference ground-based SEAD operations. Comparative analysis of OPERATION DESERT STORM and OIF shows that the employment of SOF, combined with a robust intelligence apparatus, timely targeting, and the useful application of fires, can provide decisive results.

A. THE OPERATION DESERT STORM SCUD HUNTS

In 1991, Iraqi dictator Saddam Hussein made the strategic decision to complicate U.S. involvement in OPERATION DESERT STORM by launching SCUD missiles at Israel, Bahrain, and Saudi Arabia. While not very accurate, the SCUDs served Hussein's strategy by causing significant civilian unrest in Israel.[132] In response, the United States provided the Israelis with PATRIOT air defense systems. The United States also began an air campaign to find and destroy Iraqi SCUD launchers, in hopes of keeping Israel from

[132] William Rosenau, *Special Operations and Elusive Enemy Ground Targets: Lessons from Vietnam and the Persian Gulf War* (Santa Monica, CA: RAND Corporation, 2001), 29–30.

responding.[133] However, Iraq's tactics for hiding SCUDs proved problematic to the coalition. The Iraqis launched scuds from 28 fixed sites and up to 36 mobile transporter-erector-launchers (TELs).[134] While the coalition had great success striking the fixed targets, the mobile TELs proved challenging to find and destroy. The challenge of finding SCUDs came from the coalition's lack of understanding of the intelligence picture; they simply could not find the SCUDs.[135]

Iraq further muddied the intelligence picture by disguising support vehicles as school buses; using high fidelity decoys; and utilizing gullies, waddies, and highway underpasses to conceal the TELs.[136] Iraq also sacrificed accuracy for mobility. While the Russians would take 90 minutes to set up a SCUD launcher, it took the Iraqis as little as 30 minutes.[137] Iraq also demonstrated excellent communication and emitter discipline, which complicated the coalition's targeting challenge.[138] The targeting challenge was complicated by inadequate sensor technology that prevented the coalition from effectively detecting the SCUDs even during the daytime immediately after launch.[139] Despite conducting 1,460 strikes against SCUDs, second only to strikes against fielded ground forces, the coalition air campaign against the SCUDs was mostly a failure.[140] In response, U.S. Vice President Dick Cheney approved a plan to send U.S. SOF to find and destroy the SCUDs.[141]

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133 Rosenau, 29–30.

134 Rosenau, 31–32.

135 Anthony H. Cordesman and Abraham R. Wagner, *The Lessons of Modern War, vol. IV: The Gulf War* (Boulder, CO: Westview Press Inc, 1996), 330.

136 Rosenau, *Special Operations and Elusive Enemy Ground Targets: Lessons from Vietnam and the Persian Gulf War,* 32.

137 Jeffrey E. Rucker, "Using Agent-Based Model to Search for Elusive Hiding Targets" (master's thesis, Air Force Institute of Technology, 2006), 1.

138 Cordesman and Wagner, *The Lessons of Modern War, IV: The Gulf War*, 330.

139 Rosenau, *Special Operations and Elusive Enemy Ground Targets: Lessons from Vietnam and the Persian Gulf War*, 33–34.

140 Cordesman and Wagner, *The Lessons of Modern War, IV: The Gulf War,* 329.

141 Rosenau, *Special Operations and Elusive Enemy Ground Targets: Lessons from Vietnam and the Persian Gulf War,* 35.

OPERATION DESERT STORM demonstrated that airpower alone was not enough to destroy strategic mobile ground targets.[142] Therefore, the coalition developed a plan for American and British SOF to infiltrate western Iraq to find SCUDs and related targets and enable their destruction by calling in airstrikes.[143] However, U.S. forces were not organized or equipped for such a mission.[144] For infiltrations, the teams used rotary-wing and specialized fixed-wing aircraft that allowed them to jump in from as low as 190 feet above ground level.[145] All but two of these teams chose to use modified four-wheel drive vehicles for mobility. Of the two teams that chose to go on foot patrol, one team exfiltrated immediately after infiltration because the team leader recognized that the geography was too vast. The Iraqis captured the other team on foot patrol.[146]

Due to limited intelligence and the vast desert terrain, finding, navigating to, and destroying SCUDs was difficult. Satellite and airborne assets were unable to provide timely and reliable intelligence on the SCUDs' locations.[147] Iraqi deception techniques, like decoys, also frustrated the teams. Furthermore, even when teams found SCUDs, the time from communicating targeting data to the airborne delivery of ordnance often took as long as 50 minutes.[148] Unthwarted by limited intelligence and minimal air support, the British took creative steps to accomplish their mission. For example, they provided BDA of targets struck by coalition aircraft,[149] destroyed fiber-optic links between SCUD missile systems and crews, used explosive to destroy communications infrastructure, and ambushed Iraqi convoys that supported the SCUDs.[150] Finally, in response to inadequate air support, the

142 Rosenau, 35.

143 Rosenau, 35.

144 Thomas K. Adams, "U.S. Special Operations Forces in Action: The Challenge of Unconventional Warfare" *Abingdon-on-Thames*, UK: Routledge, 1998), 242.

145 Cordesman and Wagner, *The Lessons of Modern War, IV: The Gulf War*, 331.

146 Rosenau, *Special Operations and Elusive Enemy Ground Targets: Lessons from Vietnam and the Persian Gulf War,* 37–38.

147 Rosenau, 46.

148 Rosenau, 37.

149 Rosenau, 38–39.

150 Rosenau, 28–39.

British used shoulder-fired Milan missiles to attack the SCUDs directly.[151] Despite the courage and creativity of American and British SOF, the SCUD campaign is mostly viewed as a tactical and operational level failure.

However, one could argue that the OPERATION DESERT STORM SCUD hunt was a strategic success as explained below. At best, the U.S. military assessment of the results of the SCUD hunt was exaggerated. Coalition air planners initially estimated that aircraft killed 80 total system components and SOF killed 9–12.[152] However, these claims represented 300% of the total Iraq SCUD force.[153] Military analyst William Rosenau offers a more realistic assessment: that SOF destroyed up to three SCUDs.[154] Some analysts have pointed to a reduction in total scud launches as a sign of mission effectiveness. Iraq averaged 4.7 SCUD launches per day during the first week and an average of 1.5 launches through the remainder of the war. However, this correlation is not necessarily causal and could be reflective of a change in Hussein's political objectives. It is also worth pointing out that Iraq launched as many SCUDs in the last eight days of the war as the first seven.[155] Despite these dubious tactical results, one could argue that the strategic objective of the SCUD hunt was met: Israel never entered the war.[156]

B. THE OPERATION IRAQI FREEDOM SCUD HUNTS

When the United States invaded Iraq in 2003, the U.S. military again chose SOF to hunt for SCUDs. By this time, the U.S. military had compiled years of data and identified several hundred potential launch sites. At the onset of the invasion, the Americans dedicated SOF and UAVs, in addition to manned reconnaissance and strike aircraft, to

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151 Rosenau, 38–39.

152 Rosenau, 38–39.

153 Cordesman and Wagner, *The Lessons of Modern War, IV: The Gulf War,* 331.

154 Rosenau, *Special Operations and Elusive Enemy Ground Targets: Lessons from Vietnam and the Persian Gulf War,* 40.

155 Cordesman and Wagner, *The Lessons of Modern War, IV: The Gulf War,* 332.

156 Rosenau, *Special Operations and Elusive Enemy Ground Targets: Lessons from Vietnam and the Persian Gulf War,* 43.

monitor these sites for mobile TELs.[157] Similar to OPERATION DESERT STORM, SOF was to locate mobile SCUDs and transmit targeting data to strike aircraft. These aircraft would only target SCUDs when SOF teams on the ground reported their positions in real time.[158] This standard operating procedure was in place because the SCUDs were so mobile and well-hidden that attempts to strike them with latent location information was futile.[159]

During OIF, SOF's ability to identify and destroy SCUDs was enhanced through the use of dedicated UAVs.[160] These UAVs would stream live video to C2 nodes, which would then direct strike aircraft to target and destroy the SCUDs.[161] Not only did UAVs provide real-time targeting data, but they also effectively extended the range of SOF by flying beyond visual range of the ground force.[162] The ability to target in real time with UAVs mitigated the inadequacy of using satellites for time-sensitive targeting.[163] Additionally, SOF would occupy airfields to deny their use to Iraqis who intended to use them to launch SCUDs.[164] Finally, the command relationship was such that the Combined Force Special Operations Component Command (CFSOCC) conducted the SCUD hunt in support of the air component. This command relationship streamlined the targeting process.[165] The SCUD hunt during OIF is remarkable because of its effectiveness: not a single SCUD was launched in western Iraq.[166] Furthermore, during time-sensitive

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[157] Rucker, "Using Agent-Based Model to Search for Elusive Hiding Targets," 2–3.

[158] Pazdziorek Przemyslaw, "Special Forces Transformation in Face of the Contemporary Conflicts Challenges," *Review of the Air Force Academy* 1 (n.d.): 81.

[159] Przemyslaw, 82.

[160] Malcom Brailey, The Transformation of Special Operations Forces in Contemporary Conflict Routledge, in *Military Transformation and Strategy*, 1999, 94.

[161] Przemyslaw, "Special Forces Transformation in Face of the Contemporary Conflicts Challenges," 94.

[162] Przemyslaw, 59.

[163] Rucker, "Using Agent-Based Model to Search for Elusive Hiding Targets," 68.

[164] Brailey, The Transformation of Special Operations Forces in Contemporary Conflict, 74.

[165] Brailey, 92.

[166] F Stein and Anders Fjellstedt, "Network Centric Warfare in Western Iraq" (Powerpoint Presentation, 2006), www.DODccrp.org/events/2006_CCRTS/html/presentations/026.pdf.

targeting of SCUDs, the time from locating a SCUD to weapons release was 9–17 minutes.[167]

C. ANALYSIS OF BOTH SCUD HUNTS

Comparison of DESERT STORM and OIF SCUD hunts shows that, while the strategic problem was similar, the coalition was much more effective in 2003 than in 1991. Unlike DESERT STORM, the U.S. SCUD hunt during OIF was tactically successful because the resources, methods, and strategic investment matched the problem SCUDs presented. In the future, the lessons of the OPERATION DESERT STORM and OIF SCUD hunts dictate that effective SOF employment for similar missions requires mounted mobility, organic ISR, effective target identification and discrimination, organic and timely fires, and seamless synchronization with C2 nodes. Furthermore, Rosenau suggests that reconnaissance, BDA and the employment of unattended ground sensors (UGS) by SOF to refine the intelligence picture and understand the electronic battlefield could have significant value to similar missions in the future.[168] Missile defense expert James Wirtz argues that confirmation of the destruction of strategic systems is so important that the American military must have the capability to put SOF units on the ground to guarantee that TELs are destroyed.[169] Military scholars Anthony Cordesman and Abraham Wagner echo this sentiment and recommend enhanced collection and targeting provided by dedicated intelligence teams, better deception detection capability, improved strike systems, and SOF teams that specialize in the targeting and ground-based attack of strategic mobile systems.[170] However, Rosenau cautions that the flat and open Iraqi terrain was in many ways ideal for targeting and destroying mobile systems with precision. Locating mobile systems in dense and mountainous terrain will likely be more challenging.

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167 Stein and Fjellstedt.

168 Rosenau, *Special Operations and Elusive Enemy Ground Targets: Lessons from Vietnam and the Persian Gulf War,* 40

169 James Wirtz, "Counterforce and Theater Missile Defense: Can the Army Use an ASW Approach to the Scud Hunt?," (Carlisle Barracks, PA: Army War College Strategic Studies Institute ACN-95009, 1995): 6–7.

170 Cordesman and Wagner, *The Lessons of Modern War, IV: The Gulf War*, 333.

The lessons of DESERT STORM informed the coalition SCUD hunt during OIF, and, similarly, military planners should use the lessons of both operations to inform their strategy to defeat elusive strategic targets in the future. In particular, comparing the two cases show the importance of intelligence, seamless C2, and effective integration between air and ground forces. The practice of identifying and observing potential scud launching locations and waiting for the SCUDs to arrive proved particularly useful. However, caution should be applied in drawing conclusions from the SCUD hunts and applying them directly to SOF's role in SEAD. For example, during the SCUD hunts, SOF was able to rely on air assets to assist with targeting and provide a reliable finish capability. A modern IADS could degrade air assets' ability to similarly support SOF. SOF should, therefore, consider developing robust organic fires, communication, and ISR capabilities.

The enemy situation in Iraq was such that SOF had greater freedom of maneuver than one could expect in a peer vs. peer scenario. A peer adversary's ability to effectively hunt for SOF enhances the importance of surprise, deception, security, and organic lethality. Without these improvements, the conditions for a direct role for SOF may be limited to situations where SOF can freely maneuver with the support of airpower. Therefore, against the full weight of a capable adversary, perhaps indirect roles are more applicable.

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IV. INDIRECT ROLES FOR SOF: A CASE STUDY ON ISRAELI OPERATION ORCHARD

OPERATION ORCHARD serves as a thought-provoking example of how cyber could add another dimension to SEAD while informing how SOF could indirectly contribute to air superiority on the modern battlefield. Military strategist Christopher Lamb argues that SOF's strategic value resides in its ability to serve as a force multiplier while expanding the range of options to decision makers.[171] He further argues that SOF accomplishes these strategic functions through two roles, that of the commando and that of the unconventional warrior.[172] Any analysis of emerging mission areas for SOF should consider not only direct, commando roles, but should also include the indirect, unconventional warrior roles. While there is much political hand-wringing over cyber warfare and its implications, in 2007 the Israelis provided a striking example of what scholar Thomas Rid calls cyber sabotage.[173] Code-named OPERATION ORCHARD, according to unclassified reports, the IDF used cyber and advanced electronic warfare techniques to successfully suppress Syria's IADS. At the time, Syria's IADS was one of the most capable in the world.[174]

The case of OPERATION ORCHARD provides an opportunity to analyze not only the role of cyber in support of SEAD but also to explore indirect roles for SOF. This chapter begins with a description of SOF's role as the unconventional warrior. It then discusses and analyzes OPERATION ORCHARD as a case study. Finally, it uses the lessons of OPERATION ORCHARD to inform recommendations on indirect roles for SOF in support of a SEAD campaign.

The purpose of an indirect approach is to enhance the effectiveness of decisive blows by deliberately targeting an adversary's weaknesses in a way that disorients or

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171 Christopher Lamb, "Perspectives on Emerging SOF Roles and Missions," 4.

172 Lamb, 4.

173 Thomas Rid, "Cyber War Will Not Take Place," *Journal of Strategic Studies* 35, no. 1 (2012): 16, https://doi.org/10.1080/01402390.2011.608939.

174 Rid, 16.

confuses it.[175] British military strategist Liddell Hart uses the sport of wrestling as a metaphor for the role of the indirect approach in warfare. He states, “In war as in wrestling, the attempt to throw the opponent without loosening his foothold and balance can only result in self-exhaustion increasing in disproportionate ratio to the effective strain put upon him. Victory by such a method can only be possible through an immense margin of superior strength in some form, and, even so, tends to lose decisiveness.”[176] According to Lamb, SOF provides indirect options for decision makers by training, advising, and influencing foreign forces and populations.[177] Military scholar Scott Morrison echoes this sentiment, but also argues that this capability should also include the offensive application of force.[178] An essential aspect of this relationship with foreign forces and populations is the concept of access. Morrison argues that access is not limited to infrastructure like airfields, but potentially, more importantly, by access to information.[179] Information could allow the U.S. military to be more effective on the modern battlefield because it can inform the innovation of both lethal and nonlethal capabilities against an adversary.[180] Applied correctly, indirect capabilities will allow SOF to keep an adversary off-balance and enhance the effectiveness of decisive blows, as described by Hart. In OPERATION ORCHARD, the IDF allegedly used cyber to not only support a decisive blow, but also to navigate a high-stakes and complex political environment.

A. OPERATION ORCHARD

From the spring of 2004 to summer 2007, Israel and the United States entered into a period of intelligence collection and political debate about what they thought was a facility linked to the Syrian nuclear weapons program. In early 2004, the U.S. National

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[175] Scott Morrison, “Redefining the Indirect Approach, Defining Special Operations Forces (SOF) Power, and the Global Networking of SOF,” *Journal of Strategic Security*, 7, no. 2 (2014): 49.

[176] Liddell Hart, *Strategy of the Indirect Approach*, London: Faber and Faber Limited, 1941, 4.

[177] Lamb, “Perspectives on Emerging SOF Roles and Missions, 4.

[178] Morrison, “Redefining the Indirect Approach, Defining Special Operations Forces (SOF) Power, and the Global Networking of SOF,” 50.

[179] Morrison, 53–54.

[180] Morrison, 54.

Security Agency (NSA) observed a concerning amount of communication between Syria and North Korea. They were particularly interested in the high level of phone traffic between Pyongyang and a town in northeastern Syria known as al-Kibar.[181] In response, U.S. and Israeli intelligence services increased their collection on al-Kibar. Shortly after that, the Israeli Mossad uncovered a treasure trove of damning intelligence when they stole the laptop of a Syrian government official.[182] In this laptop were pictures from inside the facility at al-Kibar to include a picture of the head of the Syrian Atomic Energy Commission standing next to a North Korean nuclear official who worked at the Yongbyon nuclear site.[183] The pictures of the facility itself were particularly concerning. Upon reviewing them, one U.S. official called the facility a replica of Yongbyon.[184] As the evidence grew, it became clear the facility was likely part of Syria's developing nuclear program. As a result, Israel requested that the United States strike the facility.[185] However, the United States was still staggering from the massive intelligence failure associated with Iraq's nuclear program and subsequent invasion in 2003.[186] As a result, on 13 July 2007, President George Bush decided not to strike the site, but instead to pursue a diplomatic approach, citing a lack of proof.[187] President Bush made this decision even though in June of the same year, Israel commandos conducted multiple reconnaissance missions of al-Kibar to take photographs and collect soil samples to confirm the nature of the site further.[188] If Israel wanted it destroyed, they would have to do it themselves.

[181] Eric Follath and Holger Stark, "The Story of Operation Orchard: How Israel Destroyed Syria's Al Kibar Nuclear Reactor," *Spiegel Online*, November 2, 2009, 3, http://www.spiegel.de/international/world/0,1518,druck-658663.

[182] Warren Bass, A Surprise Out of Zion? (Santa Monica, CA: RAND Corporation), 47, accessed February 12, 2019, https://www.jstor.org/stable/10.7249/j.ctt19w73b6.10.

[183] Bass, 47.

[184] Bass, 47.

[185] Bass, 50.

[186] Bass, 50.

[187] Bass, 54.

[188] Dan Raviv and Yossi Melman, *Spies Against Armageddon: Inside Israel's Secret Wars* (Sea Cliff, NY: Levant Books, n.d.), 315.

On 5 September 2007, a flight of IAF fighter aircraft successfully struck the al-Kibar nuclear site. Upon notification that the U.S. would take no military action, Israel began careful preparation to destroy al-Kibar. They developed three plans: an IAF strike against several locations associated with Syria's nuclear program, an IAF strike against just the suspected site at al-Kibar, or a raid at al-Kibar by Israeli SOF.[189] Concerned with political ramifications of a strike on multiple targets, Israeli political leadership chose the second option, a precision strike of al-Kibar.[190] On 5 September 2007, ten IAF fighters took off from Ramat David Air Base on what they thought was a routine exercise.[191] As they neared the Syrian border, they were given the coordinates of the site at al-Kibar.[192] Eighteen minutes later, al-Kibar was destroyed.[193] Israeli military analysts Lior Tabanski and Isaac Ben Israel argue that the alleged cyberattack on Syrian air defenses was central to the success of this mission.[194] This sentiment is supported by Thomas Rid, who offers that, while the Syrian IADS was one of the most capable in the world, they were unable to detect any of the Israeli fighters due to the Israeli cyber sabotage mission.[195] Tabansky and Israel further argue that the Israeli choice to use cyber was consistent with their strategy of minimizing collateral damage. A kinetic strike would have required the physical destruction of many air defense installations, resulting in the possible death of Syrian soldiers, civilians, and foreign advisors.[196] The Israelis had demonstrated the strategic value of the indirect approach on the modern battlefield.

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189 David Makovsky, "The Silent Strike: How Israel Bombed a Syrian Nuclear Installation and Kept It Secret," *The New Yorker*, September 17, 2012, https://www.newyorker.com/magazine/2012/09/17/the-silent-strike.

190 Makovsky.

191 Follath and Stark, "The Story of Operation Orchard: How Israel Destroyed Syria's Al Kibar Nuclear Reactor," 5.

192 Follath and Stark, 5.

193 Follath and Stark, 5.

194 Lior Tabansky and Isaac Ben Israel, Cybersecurity in Israel, *SpringerBriefs in Cybersecurity*, (2015), 65.

195 "Cyber War Will Not Take Place," 16.

196 Tabansky and Israel, "Cybersecurity in Israel," 66.

B. CYBER AND ELECTRONIC WARFARE IN SUPPORT OF SEAD OBJECTIVES

While much of OPERATION ORCHARD remains classified, the prevailing hypothesis is that the IDF employed cyber in the form of both air-to-ground and computer-to-computer network attacks. Israel's airborne cyber capabilities are reportedly similar to the U.S. military's *Suter* network invasion capability. The U.S. version of this capability includes both the EC-130 COMPASS CALL and RC-130 RIVET JOINT. The operational concept is for the EC-130 to shoot data with sophisticated algorithms into adversary radar antennas.[197] The RC-130 would then monitor adversary signals to determine if the algorithms were effective. The Israelis allegedly duplicated this capability by modifying two Gulfstream G550 special mission aircraft.[198] The other alleged aspect of the IDF cyberattack centered around a technology known as a kill switch.[199] Science writer and editor Sally Adee offers that there are two ways to manipulate a chip, with a kill switch or a back door.[200] A kill switch manipulates commercial off the shelf (COTS) software or hardware and causes it to die. A back door allows access to the chip to disable it or enable a specific function.[201] A chip saboteur could access any one of the 24 entry points in the chip design phase to modify it.[202] The generic COTS chips many defense contractors rely upon are extremely cost effective; they cost $500 where a custom chip can cost up to $50 million.[203] However, they are also easily reprogrammable. Furthermore, determining if a chip is modified is very difficult due to the chip's complexity and industry inspection practices.[204] While manipulation of microprocessors is expensive and requires skilled engineering, Israel may have shown how the investment could be worth it. During

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[197] David Fulghum, Robert Wall, and Amy Butler, "Cyber-Combat's First Shot," *Aviation Week and Space Technology*, November 26, 2007, 29–30.

[198] Fulghum, Wall, and Butler, 29–30.

[199] Rid, "Cyber War Will Not Take Place," 17.

[200] Sally Adee, "The Hunt for the Kill Switch," *IEEE Spectrum* 45, no. 5 (2008), 34.

[201] Adee, 36.

[202] Adee, 38.

[203] Adee, 38

[204] Adee, 38.

OPERATION ORCHARD, Israel was able to render the Syrian IADS obsolete without destroying any infrastructure or killing anyone.[205]

While OPERATION ORCHARD serves as an inspiring example of the potential of cyber in support of SEAD, the addition of such a capability in U.S. SEAD doctrine requires careful analysis of its limitations. When supporting SEAD, cyberattacks should be considered complex military and intelligence operations with a goal deceiving the IADS.[206] Successful cyber operations should confuse and mislead adversary decision makers. Like other aspects of military deception, cyber tools are often single use; once they are discovered, they become irrelevant.[207] Additionally, cyberattacks require significant investments in technology and time.[208] Cyber professionals require training and sophisticated equipment. Furthermore, each capability must be tailored for use against specific systems or networks.[209] Therefore, successful cyber operations require substantial investment in network reconnaissance and delivery mechanism development.[210] Even when useful tools are developed, cyber operations can be thwarted relatively easily if an adversary updates software, hardware, and TTPs.[211] Because of the advanced planning and investment required to develop a viable cyber operation, cyberattack is best suited for

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[205] Raviv and Melman, *Spies Against Armageddon: Inside Israel's Secret Wars*, 321.

[206] Shane Quinlin, "Jam, Bomb, Hack? New U.S. Cyber Capabilities and the Suppression of Enemy Air Defenses," *Georgetown Security Studies Review*, April 7, 2014, http://georgetownsecuritystudiesreview.org/2014/04/07/jam-bomb-hack-new-u-s-cyber-capabilities-and-the-suppression-of-enemy-air-defenses/.

[207] Quinlin.

[208] Fred Cohen, "Simulating Cyber Attacks, Defenses, and Consequences," *Fred Cohen and Associates*, March 1999, http://all.net/journal/ntb/simulate/simulate.html.

[209] Jason Andress and Steven Winterfield, Cyber Warfare: Techniques, Tactics, and Tools for Security Practitioners (Elsevier, 2013), 119.

[210] Eric Hutchins, Michael Cloppert, and Rohan Amin, "Intelligence-Driven Computer Network Defense Informed by Analysis of Adversary Campaigns and Intrusion Kill Chains," Lockheed Martin Corporation, 2009, http://www.lockheedmartin.com/content/dam/lockheed/data/corporate/documents/LM-White-Paper-Intel-Driven-Defense.pdf.

[211] Quinlin, "Jam, Bomb, Hack? New U.S. Cyber Capabilities and the Suppression of Enemy Air Defenses."

deliberately planned operations.[212] Cyber is likely to be less useful in reacting to a crisis where lead times are truncated.[213]

C. INDIRECT ROLES FOR SOF IN SUPPORT OF SEAD OBJECTIVES

Using OPERATION ORCHARD as a template, SOF's indirect roles could mirror IDF's concept of employment whereby SOF could provide or enhance both a remote electronic attack capability and the development of COTS tools like the microprocessors used as kill switches. Given the range of Russian-made strategic SAMs, aircraft may not be able to get within range to use *Suter* or similar capabilities. SOF, therefore, could potentially gain access to a location inside a strategic SAM's range and use proximity to more effectively jam or deceive it. Additionally, SOF could work with its foreign partners to locate mobile air defenses and assess how and when an adversary will move them around the battlefield. Furthermore, with access, SOF could passively analyze the signals environment around air defense systems to support the development of electronic warfare and cyber tools. Lastly, SOF could work with its foreign partners to identify vulnerabilities in the COTS microprocessor development and distribution process to support kill switch development. OPERATION ORCHARD serves as a springboard to analyze how SOF could use indirect approaches to keep air defenses and their associated C2 nodes off balance.

OPERATION ORCHARD demonstrated how cyber and advanced electronic warfare techniques could provide a third option for SEAD in addition to jamming and physical attacks. However, cyber comes with limitations that need to be considered. Cyber tools are expensive, one-off, and often single use so are best suited for deliberately planned operations. Fortunately for SEAD planners, SOF is in the position to use indirect capabilities to provide economy of force options that expand choice for decision makers. SOF can use its relationships with partner military and populations to gain information on the location, disposition, and signals environment associated with modern mobile SAMs.

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212 Quinlin.

213 Quinlin.

This information could be used for not only targeting, but also developing electronic warfare and cyber tools.

Furthermore, SOF can use its ability to penetrate enemy territory to access locations inside SAM range and reduce an IADS' ability to understand its environment adequately and target aircraft. These tasks require significant investment in classified research to develop the appropriate tools and TTPs to ensure operational success. However, the advancement of modern air defenses has resulted in a scarcity of viable options. Creative solutions are necessary, and SOF is in a position to provide such answers.

V. CONCLUSION

A. ANALYSIS

The ability to find and fix mobile air defense systems is as at least as important as the capability to suppress or destroy them. Winning the fight for information dominance will increase not only survivability of attack aircraft, but also lethality. The U.S. military may find this task even more difficult against future adversaries because it has mostly fought in desert terrain for the last 30 years. As seen in Kosovo in 1999, targeting mobile SAMs becomes difficult if an adversary can utilize mountainous, forested terrain to hide them. Additionally, as seen in Vietnam in the 1960s and 1970s, Kosovo in 1999, and Iraq in 1991 and 2003, air defenders who exercise emitter discipline can confuse SEAD targeting and be dangerous to SEAD assets if they employ the technique of shooting volleys of missiles without guidance. The role of intelligence, therefore, is of central importance. Comparative analysis of the SCUD hunts in 1991 and 2003 shows that thorough intelligence preparation of the battlespace will allow SEAD planners to not only locate IADS components, but also identify alternate locations for moving mobile systems. UAVs can also have a critical role in a SEAD campaign. Not only can UAVs locate mobile systems by streaming high-definition video, but they can also draw fire from air defenses to assist in the targeting problem. UAVs expand the visual range of ground forces, which makes them more effective in finding mobile systems across a vast terrain. Finally, as seen in OPERATION UNIFIED EFFORT in the Vietnam War in the early 1960s, UAVs could be used to collect information within the signals environment associated with IADS to enable the development of jamming or other signals exploitation tools.

This thesis demonstrates that winning the information fight is not only about the quality and quantity of information, but also the recency of it. Fighter aircraft, anti-radiation missiles, and air defense missiles travel at several times the speed of sound. In these situations, time is measured in seconds or less. Military scholar James Brungess argues that the demand for real-time targeting data is further supported because of how quickly IADS components can be turned on and off, moved, and their frequencies and waveforms changed.[214] He argues that while most attacking aircraft prefer targeting data not less than five minutes old, SEAD assets require reliable targeting data "on demand.[215] In comparing the SCUD hunts of 1991 and 2003, SOF was much more effective in destroying strategic mobile systems when the communications and command and control infrastructure was such that the length of time between communicating the location of a system and weapons release was as brief as possible. Analysis of this study also indicates that satellites are not ideal in supporting intelligence requirements during the prosecution of time-sensitive targets because the periodicity of their orbits inhibits real-time intelligence updates. The inadequacy of satellites in time-sensitive targeting further supports the role of SOF to locate air defenses and provide targeting data in real time.

B. FAVORABLE CONDITIONS FOR SPECIAL OPERATIONS MISSIONS IN SUPPORT OF SEAD OBJECTIVES

There are four favorable conditions for the employment of SOF in SEAD: when there are advanced, long-range air defense systems on the battlefield; when the IADs will likely overwhelm air-centric approaches; when there are opportunities to disrupt or degrade air defenses before conflict; and when traditional IADS targeting methods are insufficient.

1. Condition One

The first condition for the employment of SOF appears when real-time targeting or suppression of an air defense node is required inside the engagement zone of advanced, long-range systems. SOF is uniquely postured, like the U.S. SOF helicopter crews in OPERATION DESERT STORM in 1991, to exploit air defense planners' tendency to focus resources up and out for high-flying and fast-moving air assets. Given the devastating nature of these advanced long-range air defenses, SOF could demonstrate its strategic utility by infiltrating near an IADS component to locate, jam, or destroy it. SOF could also conduct high-risk, direct action raids to steal IADS components for understanding and exploiting them, as the British did during OPERATION BITING in 1942 and the Israelis

214 Brungess, Setting the Context: Suppression of Enemy Air Defenses and Joint Warfighting in an Uncertain World, 202–3

215" Brungess, 202–3.

did during the Arab-Israeli conflicts. SOF's ability to conduct BDA and provide these assessments in real-time could dramatically improve situational awareness for commanders. Proximity, in this case, may also expand commanders' options to exploit the signals environment and jam or spoof IADS components. As demonstrated during OPERATION ORCHARD in 2007, suppressing IADS through non-kinetic means, instead of outright destroying them, could help decision makers navigate a strategically complex environment.

2. Condition Two

The second condition that could drive SOF's inclusion in a SEAD campaign would be when an IADS is of similar capability to attacking air forces. During the Yom Kippur War in 1973, it was not until the Israelis included conventional ground forces and SOF in the SEAD campaign that they saw decisive success against Egyptian IADS. That case substantiates the notion that air and ground assets working together against air defenses have synergistic effects whereby, as ground assets destroy IADS components, air assets are better able to support ground assets with ISR, mobility, interdiction, CAS, MEDEVAC, and CSAR. The demand for SOF in SEAD arises when an adversary's IADS are robust enough to drive a joint approach or if the capabilities of a particular system are such that traditional options prove inadequate. This condition also accounts for the notion of a lost opportunity cost in vectoring high-dollar assets for SEAD when they could otherwise be used to destroy other strategic targets. By supporting a SEAD campaign, SOF could allow for the repurposing of dozens of aircraft and missiles required to destroy a strategic system in support of a commander's other priorities.

3. Condition Three

Crucially, the third condition for SOF's role in SEAD occurs before a conflict. As IADS components are acquired, assembled, and fielded, they are vulnerable to exploitation. Indirect approaches such as intelligence gathering to locate systems or potential sites could inform an air campaign. OPERATION ORCHARD demonstrated how the ability to interdict supply chains to introduce microprocessors or other similar tools could allow commanders to suppress air defenses indirectly and with misattribution. The CIA's

OPERATION UNIFIED EFFORT during the Vietnam War demonstrated how the signals environment associated with air defense networks could be exploited to increase the survivability of air forces. However, where this operation fell short is that it did not occur until well into the conflict and many lives were lost. Instead, decision makers could consider employing SOF to proactively understand and exploit air defense signals before a conflict. SOF should consider emplacing UGS in advance of conflict. These devices could potentially remotely assess, jam, or spoof IAD components. By proactively employing measures to suppress air defenses, SOF could increase the survivability of SEAD assets.

4. Condition Four

The fourth and final condition for SOF's role in SEAD occurs when the targeting challenge is such that conventional intelligence capabilities are insufficient. The U.S. military was faced with a daunting SEAD challenge in 1999 because the Serbs used mountainous terrain, mobile air defense components, and emitter discipline to their advantage. In response, according to a body of reporting, the United States used covert action and cyberattack to locate and suppress Serbian air defenses. In similar cases, SOF is postured to conduct intelligence operations or provide other indirect capabilities to locate and suppress IADS components. When enemy TTPs make kinetic targeting difficult, SEAD planners should also emphasize deception. Through proximity or indirect approaches, SOF could support a deception campaign that includes employing cyber to direct IADS to false targets. Finally, as the British SAS did during the OPERATION DESERT STORM SCUD hunt, instead of engaging specific IADS components, SOF could provide unconventional sabotage options like destroying fiber-optic links between missile systems and crews, using explosives to destroy communications infrastructure, and ambushing patrols that support IADS infrastructure.[216]

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[216] Rosenau, *Special Operations and Elusive Enemy Ground Targets: Lessons from Vietnam and the Persian Gulf War*, 28–39.

C. IMPLICATIONS AND RECOMMENDATIONS FOR U.S. SOF

1. Recommendation One

Despite the strategic problem IADS present and SOF's unique ability to help solve it, U.S. SOF has capability gaps it first must fill. First, infiltrating enemy territory that is protected by advanced IADS is a significant challenge. Once inside the missile engagement zone of modern SAMs, SOF rotary-wing or fixed-wing mobility assets will be exposed to the same threats as other air assets. Rotary and fixed-wing transportation is a strategic problem for SOF that must be addressed if the U.S. military expects to succeed against peer or near-peer adversaries.

2. Recommendation Two

As previously discussed, real-time situational awareness is a necessary condition for the success of a SEAD campaign. If SOF were to support such a requirement through reconnaissance, it should be able to communicate with commanders in real-time. However, adversaries will almost certainly attempt to exploit the communication of any foreign military element operating inside its borders. To overcome such a challenge, U.S. SOF should develop technology and TTPs to avoid detection when communicating both line of sight and over-the-horizon. Ironically, reinvigorating "low-tech" TTPs and technology like Morse code or High-Frequency antennas could be instrumental to success on the "high tech" battlefield. Finally, U.S. SOF should consider developing purpose-built and man-portable anti-radiation missiles or UAVs. Similar to the British SAS TTP of firing shoulder-launched Milan missiles at SCUDS and the Israeli SOF TTP of using the ze'ev purpose-built anti-radiation missiles during OPERATION PEACE FOR GALILEE in 1982, U.S. SOF could increase its survivability and lethality with precision missiles and swarming UAVs.

3. Recommendation Three

Due to the risk, complexity, and strategic importance of SEAD missions, SOF should consider institutionalizing its contribution to air superiority under one component. The U.S. Air Force has prioritized and resourced SEAD as a priority mission area since the

Vietnam War and, in many ways, is leading the development of TTPs against modern IADS, as exemplified by the establishment of the F-35 Weapons School in 2015 and the school's designation as the U.S. Air Force's lead for SEAD capability development against modern air defenses. Partnership with the fifth-generation fighter and low-observable aircraft community is instrumental for ground forces success on the modern battlefield. The Air Force Special Operations Command (AFSOC) has historical relationships with the fighter and bomber community because of its role in integrating air and ground forces and may be the command of choice to lead such an effort. The narrative associated with current U.S. military strategy espouses much about "multi-domain" approaches. AFSOC is uniquely qualified to provide a ground approach to what is traditionally an air-centric problem. In this way, the U.S. military can take a practical step towards multi-domain dominance through an unconventional approach that attacks an adversary in a way it does not expect.

APPENDIX. RELATED WORK[217]

A. A SYSTEM DYNAMICS MODEL OF SEAD SUPPORTED BY SOF

1. Purpose and Methodology

A mixed-methods (qualitative and quantitative) approach was used to model the relationship between SEAD assets and modern IADS. The initial system boundary was composed of a single 5th generation fighter aircraft such as the F-35 engaging a single S-400 SAM. However, the model was increased to an operational scope and included multiple SEAD assets conducting three strikes against IADS over the course of a 25-day campaign, which allowed for the modeling of feedback and information delays between strikes that must be considered in operational planning and execution.

The purpose of this chapter is to offer a system dynamics model to provide insights that could help refine commanders' understanding of the potential for SOF to be used as a force multiplier in a SEAD campaign. Modeling special operations effects at 10-day intervals resulted in significant improvements in the degradation of opposing IADS' capability in denied areas, while demonstrating the importance of understanding and anticipating the delays in information, feedback, and perception commonly observed when two systems interact. This new approach to understanding SEAD provides commanders an increased awareness of appropriate offensive options. The model is presented in an action/counter-action format.

2. Causal Loop Diagram (CLD) and Model Development

Model development began by identifying the requisite factors that supported a red (IADS) kill chain initiated by a blue (SEAD) air package. We selected these colors to

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217 This previously unpublished system dynamics model is the result of a three-month project at the Naval Postgraduate School and is reproduced here by permission of the authors. The project was accomplished by Lt Col David Toepher, Mr. Dan Herrington, Maj Phil Garito, and MAJ Jonathan Mleynek. Lt Col Toepher is a special tactics airman with 16 years of military service. Mr. Harrington is a PhD candidate at the Naval Postgraduate School and analyst for the Office the Secretary of Defense—Cost Assessment and Program Evaluation (OSD-CAPE). Maj Phil Garito is an AC-130 targeting officer and USAF Weapons School graduate. Maj Mylenek is a former air defense officer in the U.S. Army.

simplify the modeling process by allowing us to more easily organize variables. We then expanded the complexity of this relational feedback to determine whether the behavior resulting from this feedback was balancing or reinforcing as depicted in Figure 1.

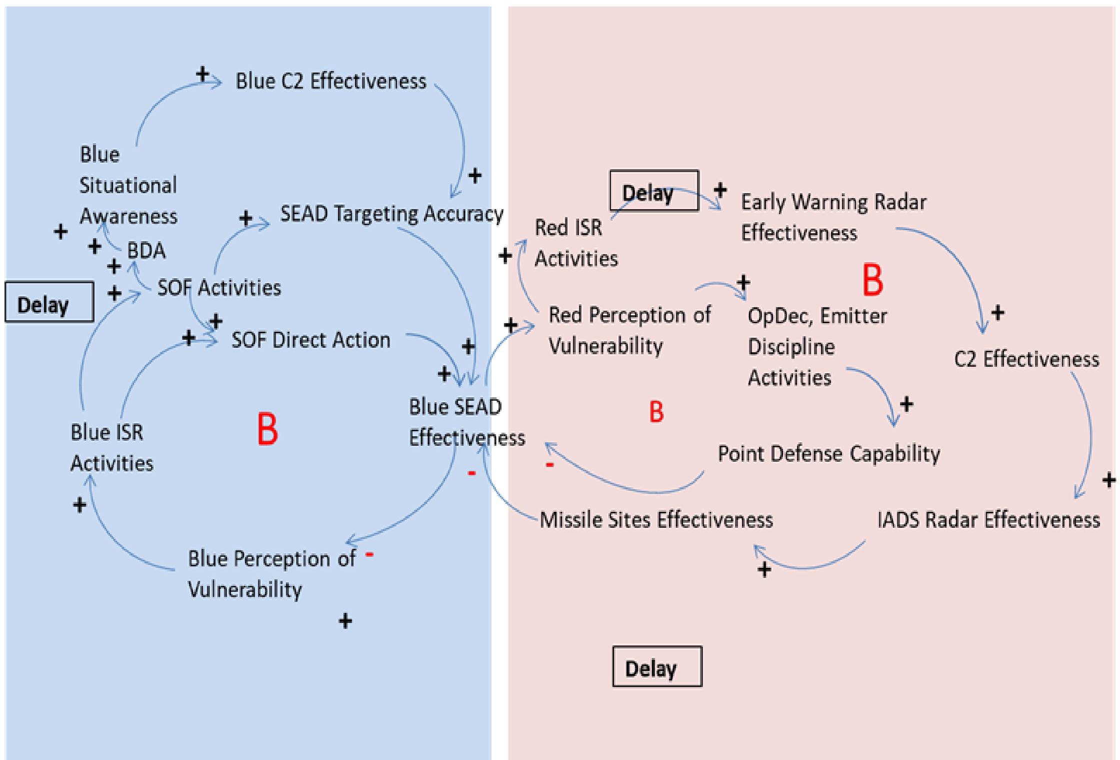

Figure 1. Causal Loop Diagram

The arrows in a causal loop diagram indicate causal relationships with polarity notations that signify the effect of each independent variable on its linked dependent variable. A "+" sign indicates that an increase or decrease in the independent variable causes a corresponding (reinforcing) increase or decrease in the dependent variable while a "-" sign indicates that an increase or decrease in the independent variable causes an opposite (balancing) effect in the dependent variable. Within each causal loop, an "R" indicates the overall effect is Reinforcing; a "B" indicates the overall effect is Balancing (Porter, eds Gil-Garcia, Pardo, & Luna-Reyes, 2018).

3. The Model

We developed this stock-and-flow model with Stella software, distributed by ISEE systems. Stella is a visual programming language commonly used in system dynamics modeling and simulation.[218] The IADS (red labeled icons) modeled in the Stella program, as displayed in Figure 2, is a quantifiable, integral calculus-based representation of the CLD displayed previously. The model shows the generation of SEAD assets interacting through an IADS kill chain that then degrades the SEAD force and a stock and flow structure that degrades the IADS' air defense. In the model, a rectangle represents a stock or system state in time that is an integral accumulation based upon the differential in-flow and out-flow rates, depicted by valves in the model. Variables that contribute to the rate equations of the in-flows and outflows are called converters and are depicted in the model by circles. The equations, variables, and constants used for this model can be found in the Appendix.

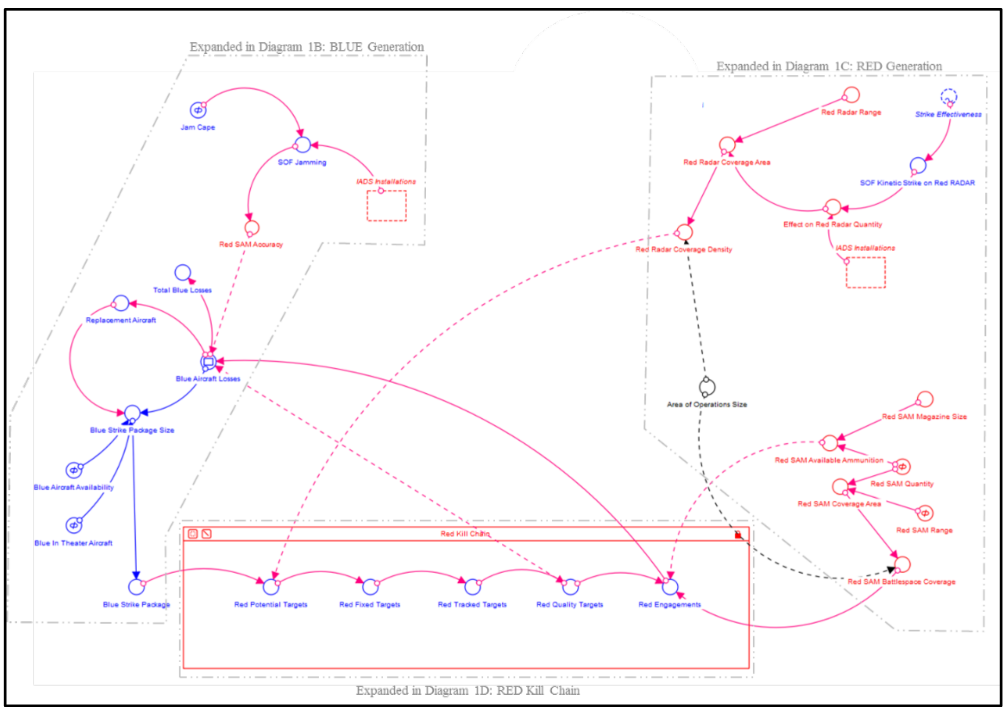

Figure 2. The Model in Stella

218 "STELLA (Programing Language)," accessed April 24, 2019, en.wikepedia.org.

4. IADS Generation

The gauge of success in this model, measured by the "IADS Installations" stock, is depicted in Figure 3. The IADS begins the simulation with three installation systems. Each of these systems contains four missile launchers with each launcher holding four missiles. As soon as the SEAD force generates an outflow (a reduction in installations or portions thereof), the "New site Added" inflow begins to regenerate IADS. The IADS regeneration is constrained by the available ammunition and has a delay to represent the initiation of new, or the repair of damaged, systems. The calculation for the flow of ammunition available from IADS force generation into the IADS Installation stock is through the SAM Available Ammunition converter and the "New Site Added" inflow. This is depicted in Figure 4.

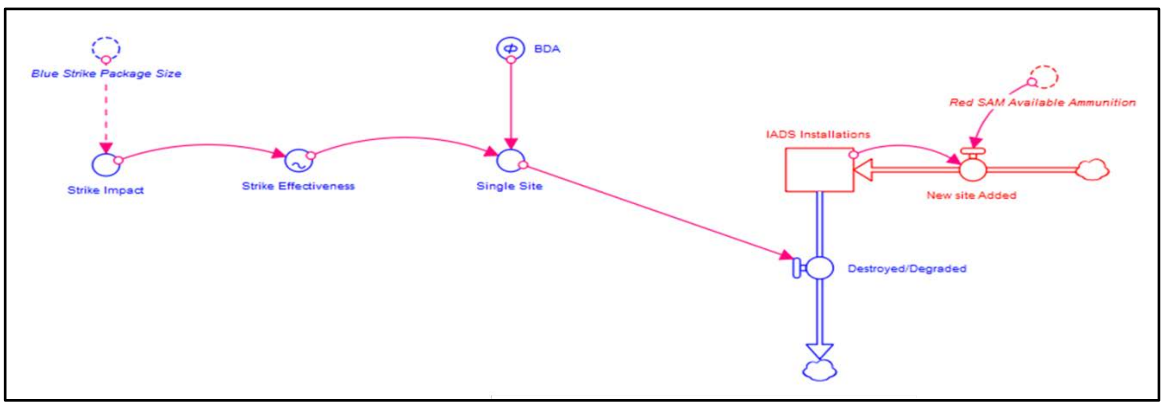

Figure 3. IADS Stock and Flow

The damaged or destroyed systems are removed from the stock through the "Destroyed/Degraded" outflow. This outflow from the IADS stock is driven by the number of SEAD forces generated that survived the IADS kill Chain (Figure 4) and is further reduced by "Strike Effectiveness," as well as an accuracy and target fidelity factor enhanced by battle damage assessment, "BDA." The "Strike Effectiveness" converter takes the size of the SEAD force and assigns a probability of successfully degrading the target that is proportionally related to the size of the force reaching the target during that time. For example, if the size of the force is three, then the probability of success is 0.011.

However, if the size of the force is 30, then the probability of success is 0.915. This calculation attempts to model the mass effect of having more targets than the IADS is capable of handling in a timely manner. The "BDA" converter further enhances the probability of successful SEAD engagements to simulate the information feedback of having SEAD assets successfully hit a valid target.

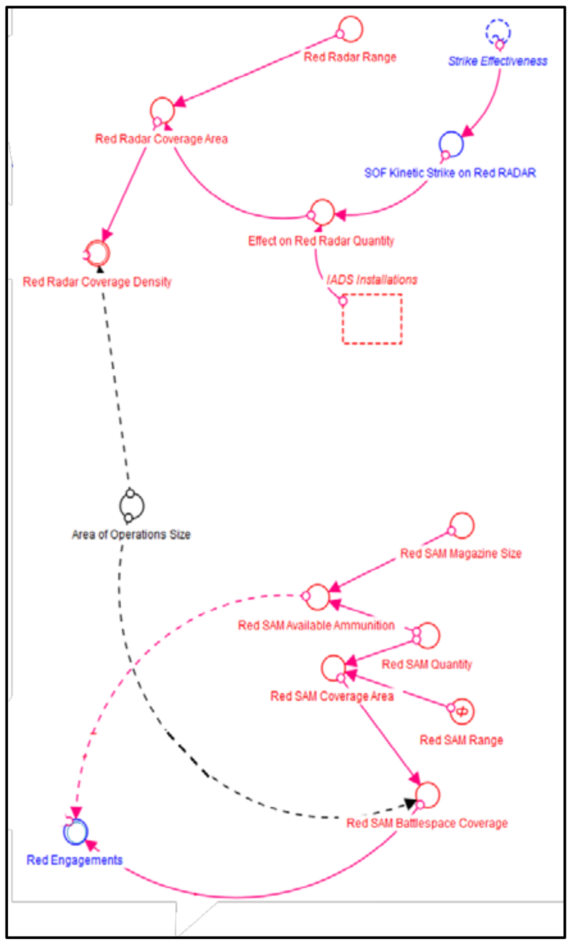

Figure 4. IADS Generation

5. SEAD Asset Generation

The SEAD forces assemble as seen in Figure 5. The “Blue Aircraft Availability” factor is a constant set at 80% that simulates the reduction of the available SEAD aircraft in theater through maintenance or other restrictive decisions. These available aircraft are then compiled into a strike package, “Blue Strike Package Size,” that accounts for aircraft losses and regeneration rates after the first strike iteration is run. This reduction occurs after the SEAD force has passed through the IADS Kill Chain (Figure 6), and we calculated it by the “Blue Aircraft Losses” converter.

The “Blue Aircraft Losses” converter produces a binomial distribution that factors in RED quality targets and engagements from the IADS Kill Chain as trials, then produces a probability based on the accuracy of SAMs through the “Red SAM Accuracy” converter. SAM accuracy is impacted by SOF jamming initiated by the outflow of the “IADS Installation” stock and driven by an exponential smoothing function contained in the “SOF Jamming’ converter” to simulate the decision and execution delay between assessing the need for SOF jamming and the deployment of these forces. The “SOF Jamming” converter slowly builds to a jamming capability that reduces IADS accuracy by 33%. The SOF jamming capability can be adjusted through the “Jam Cape” converter to show the impact it has on the system. SOF jamming reduces SEAD asset losses in the strike package as time progresses, if the SEAD force is having a detrimental effect on the IADS. The detrimental effect begins for the IADS when the “Blue Strike Package” converter puts its first of several pulses “Blue Strike Package Size” into the IADS Kill Chain. These pulses occur with time steps between each strike to simulate information delays and the introduction of new tactics/capabilities that, in-turn, provide feedback for both the IADS and SEAD assets.

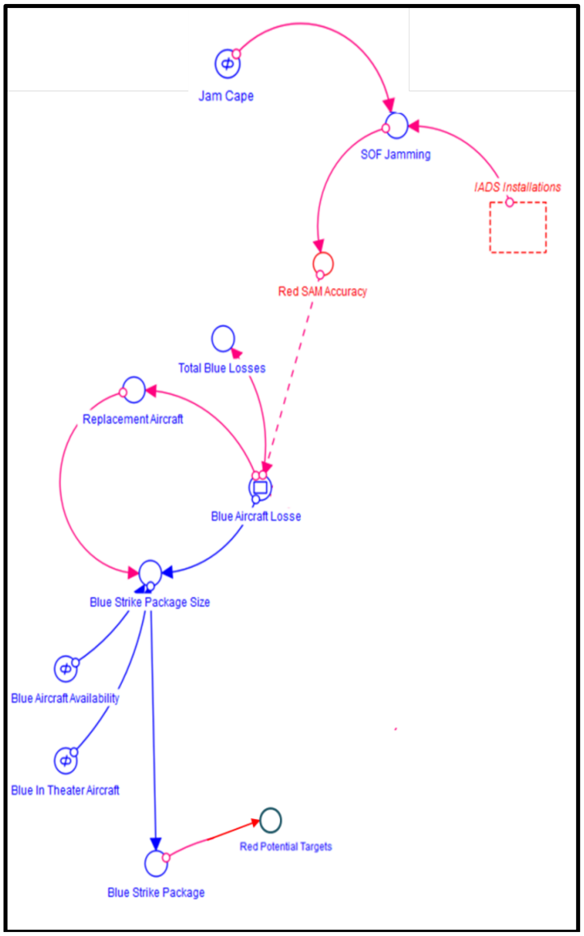

Figure 5. SEAD Asset Generation

6. The IADS

The converters in Figure 4 use distance, speed, and number of systems to calculate a sphere of engagement for the IADS. Additionally, these converters create a coverage density factor to strengthen the RED kill chain. The IADS' sphere of engagement is impacted after the first pulse by SEAD asset strike effectiveness and calculated in the "SOF Kinetic Strike on Red RADAR" converter. The "SOF Kinetic Strike on Red RADAR" only initiates when SEAD asset strike effectiveness is less than 80% and slowly degrades the radar coverage over time through an exponential smoothing function that builds to a 33% degradation of the IADS' radar over time, which simulates the use of other options when air strikes are becoming ineffective. It results in an IADS force degradation and a corresponding increase in SEAD strike effectiveness.

The IADS Kill Chain in Figure 6 creates a reduction in SEAD assets as they progress further into the IADS engagement zone. The "Red Potential Targets" converter initiates the reduction of SEAD assets. Each subsequent converter in Figure 6 builds upon delays to slow SEAD asset movement while decreasing the time the IADS takes to engage. Each converter step simulates the increasing accuracy of the IADS as the SEAD assets progress through the engagement zone, resulting in larger portions of the SEAD package being engaged by the IADS culminating with "Red Engagements." The "Red Engagements" converter uses the lower number of targets or available ammunition and feeds that into the "Blue Aircraft Losses" converter described earlier.

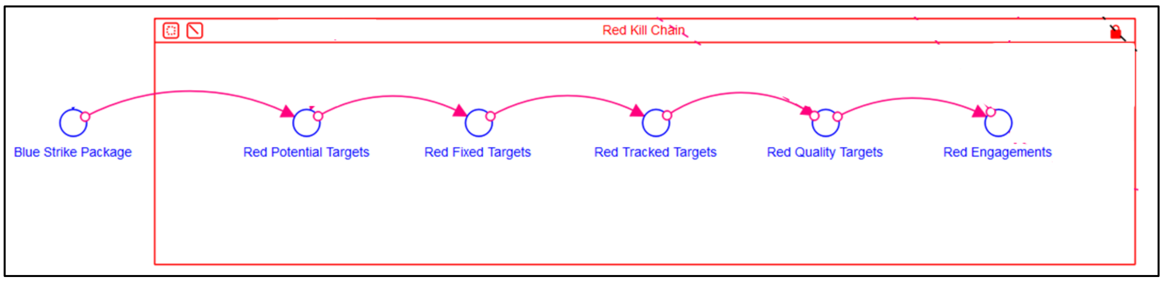

Figure 6. IADS Kill Chain

7. Findings

System dynamics offers policymakers a visualization of the interaction between SEAD assets and a modern IADS. Furthermore, this approach to achieving and maintaining air-superiority against advancing IADS provides an enhanced understanding of factors that impact both friendly and enemy decision-making processes and resultant effectiveness. The model-building process and subsequent simulation resulted in three key findings.

The first major finding is that system dynamics can be used to model a series of tactical events and to evaluate how structural feedback drives operational decisions. By expanding the time of this model from seconds to days, and by pulsing three tactical events over the course of time, we were able to simulate how commanders could adapt their SEAD strategy to include SOF jamming, Battle Damage Assessments, and kinetic strikes. Furthermore, by spacing out each of the strikes over the course of 10 days, we were also able to account for delays in decision making due to information availability. The interface depicted in Figure 7 demonstrates the value of the systems approach and Stella software in allowing decision makers to change key variables and, thereby, to evaluate behavioral system effects over time. Note the inflection point when there are 38 aircraft in the SEAD package: the IADS goes from remaining active at 25 days to being decimated at 8 days.

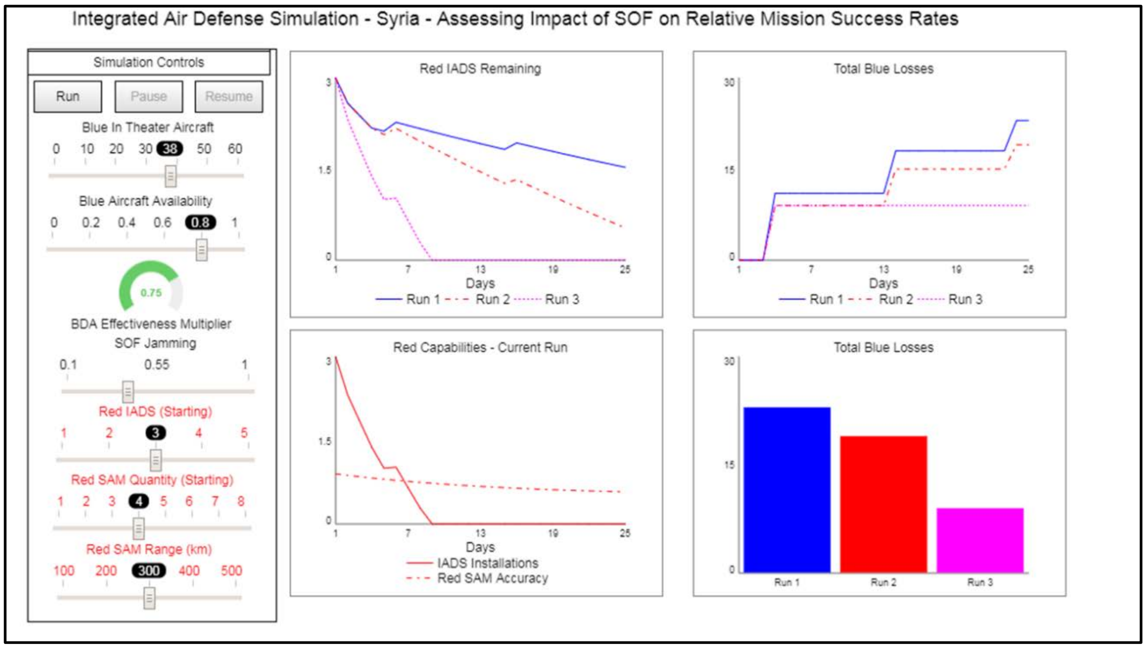

Figure 7. IADS Degradation at 38 SEAD Asset Inflection Point

The second finding is that by reducing the number of radars degrading SAM accuracy and increasing the overall effectiveness of SEAD assets, SOF can increase the overall effectiveness of a SEAD campaign. In the model, decision makers were able to compensate for the IADS' ability to regenerate by tasking SOF to conduct kinetic strikes on these systems. Furthermore, SOF was able to increase the effectiveness of SEAD strikes by conducting BDA on targets struck thereby enhancing battlespace awareness. Finally, SOF was able to reduce the IADS ability to target SEAD assets by jamming IADS radars and reducing their accuracy. The ability to jam radars from close fills a critical capability gap. Figures 8, 9, and 10 depict the injection of SOF after the first strike significantly reduces aircraft losses and increases the effectiveness of SEAD asset in a SEAD campaign.

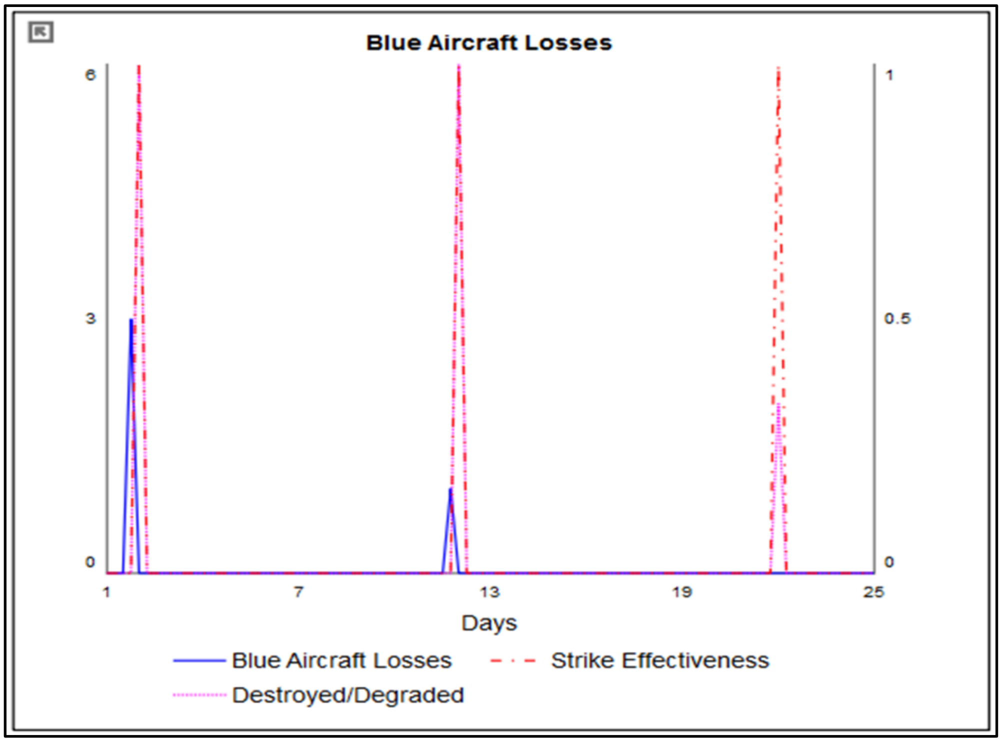

Figure 8. Reduction in Blue Aircraft Losses Due to SOF

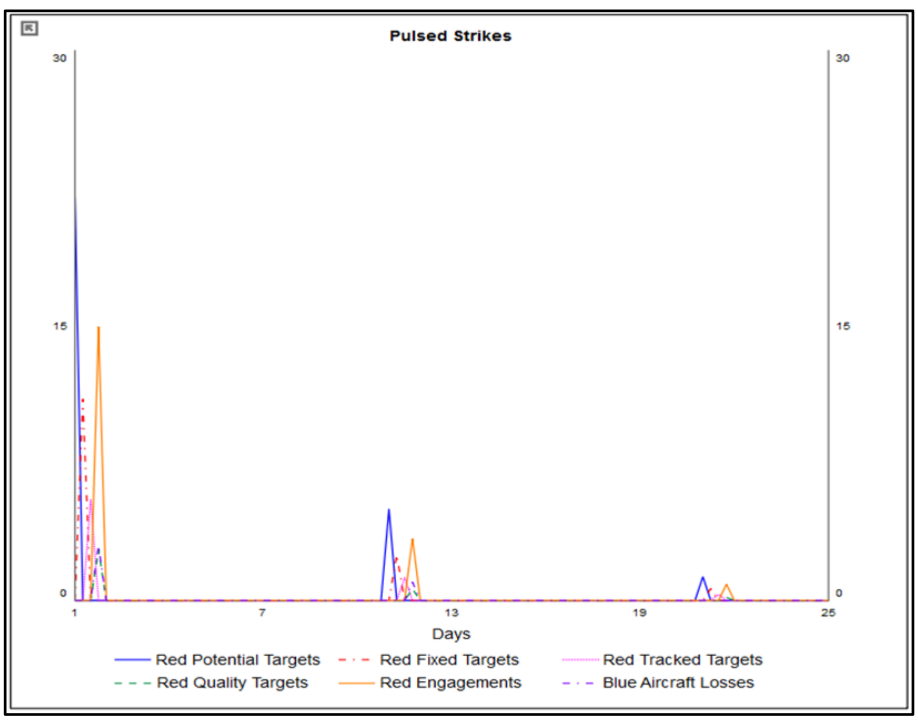

Figure 9. Reduction in IADS Targeting Capability Due to SOF

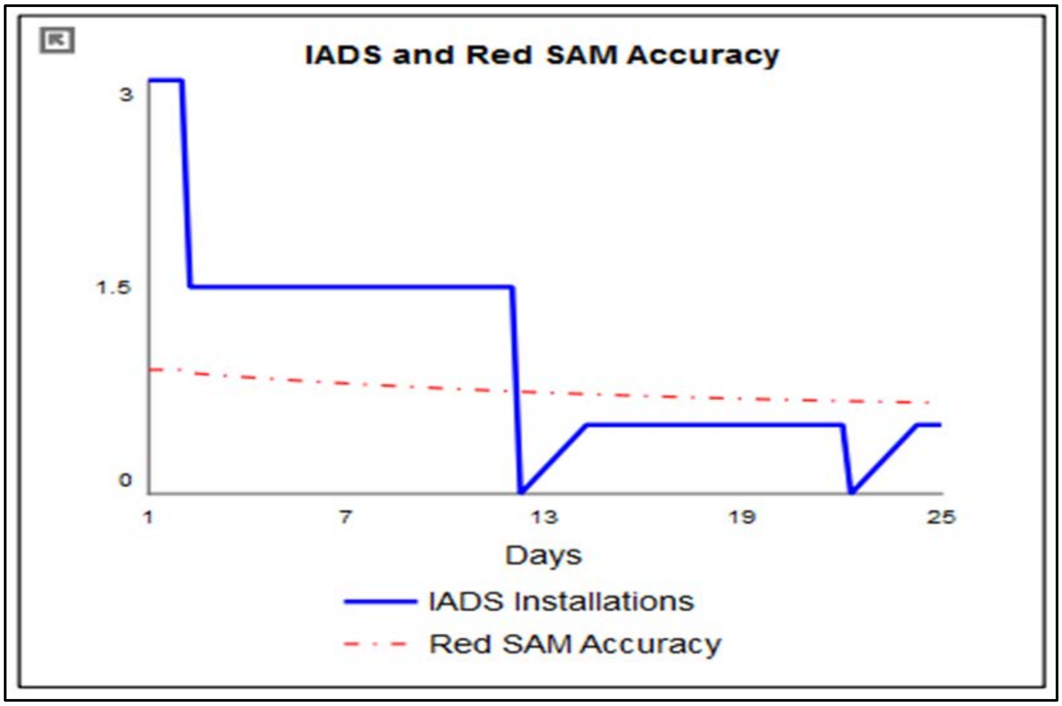

Figure 10. Reduction in IADS Installations Due to SOF

8. Future Work

Enhancement of the model could allow for more effective war-gaming. However, strategists should consider four key aspects of the model. First, the targeting challenge is simplified as the model is currently constructed and overemphasizes the number of SEAD assets. As such, future modelers should address critical aspects of modern IADS to include mobility, camouflage, and decoys. They should also consider developing a SEAD kill chain similar to the IADS kill chain, which would facilitate a more detailed evaluation of the extent to which deviations in SEAD assets' ability to effectively find and fix IADS components impacts their effectiveness and survivability. In an actual SEAD campaign, the number of assets will not matter if they cannot find and fix their targets in real time.

Second, as the model exists currently, SEAD asset generation is based on a fixed number of strike aircraft and replacement rate. Future strategists should adjust to allow for a SEAD asset stock that would account for a greater fidelity in the assets available per pulse. Third, the effectiveness of BDA and SOF jamming is currently based on a probability percentage. The fidelity of these probability percentages could be enhanced by more detailed analysis of tools and TTPs available to SOF in support a SEAD campaign. Finally, future war-games should be run, stochastically, multiple times to ensure decision makers understand the results of the campaign as the mean of many iterations.

B. EQUATIONS USED IN THE SYSTEM DYNAMICS MODEL

ICON LABEL	ASSOCIATED EQUATION
Stock and Flow, Diagram 1A	
IADS Installations (Stock)	IADS_Installations(t) = IADS_Installations(t - dt) + (New_site_Added - "Destroyed/Degraded") * dt {NON-NEGATIVE} INIT IADS_Installations = 3
New Site Added (Inflow)	IF(IADS_Installations <2.9) THEN ((((Red_SAM_Available_Ammunition)-(IADS_Installations))/Red_SAM_Available_Ammunition*0.25)*DT) ELSE 0 {UNIFLOW}
Red SAM Available Ammunition	<GHOST Function, See converter equation from RED Generation, Diagram 1C>
Destroyed/Degraded	Single_Site {UNIFLOW}
Single Site	Single_Site = Strike_Effectiveness*(BDA/(DT))
BDA	<Constant>=0.8 (Current State, but run as adjustable accuracy measure or percentage from 0-1)
Strike Effectiveness	Strike_Effectiveness = GRAPH(Strike_Impact) (0.00, 0.000), (3.00, 0.011), (6.00, 0.032), (9.00, 0.069), (12.00, 0.106), (15.00, 0.154), (18.00, 0.223), (21.00, 0.319), (24.00, 0.431), (27.00, 0.585), (30.00, 0.915)
Strike Impact	Strike_Impact = PULSE(Blue_Strike_Package_Size, 1, 1)
Blue Strike Package Size	<GHOST Function, See converter equation from BLUE Generation, Diagram 1B>
BLUE Generation, Diagram 1B	
IADS Installations	<GHOST Function, See Stock Equation from Stock and Flow, Diagram 1A>
SOF Jamming	SOF_Jamming = IF IADS_Installations < 2.99 THEN SMTH1(Jam_Cape,15, 0) ELSE 0
Jam Cape	<constant>=0.3 (used to initiate the SOF Jamming converter, used as adjustable value to demonstrated impact when changed)
Red SAM Accuracy	Red_SAM_Accuracy = .9-SOF_Jamming
Blue Aircraft Losses	Blue_Aircraft_Losses = BINOMIAL(MIN(Red_Quality_Targets, Red_Engagements), (1-(1-Red_SAM_Accuracy)^(Red_Engagements/MAX(Red_Quality_Targets, 1))))
Total Blue Losses	Total_Blue_Losses = PREVIOUS(SELF, 0)+Blue_Aircraft_Losses
Replacement Aircraft	Replacement_Aircraft = Blue_Aircraft_Losses
Blue Strike Package Size	Blue_Strike_Package_Size = MIN(Blue_In_Theater_Aircraft-Blue_Aircraft_Losses, PREVIOUS(SELF,Blue_In_Theater_Aircraft*Blue_Aircraft_Availability)+DELAY(Replacement_Aircraft, 2, 0)+DELAY(-Blue_Aircraft_Losses, 1, 0))
Blue Aircraft Availability	Blue_Aircraft_Availability = .8
Blue in Theater Aircraft	Blue_In_Theater_Aircraft = 30
Blue Strike Package	Blue_Strike_Package = PULSE(Blue_Strike_Package_Size*DT, 1,10)
RED Generation, Diagram 1C	
Strike Effectiveness	<GHOST Function, see converter equation in Stock and Flow, Diagram 1A>
SOF Kinetic Strike on Red RADAR	SOF_Kinetic_Strike_on_Red_RADAR = IF(Strike_Effectiveness<.80) THEN SMTH1(.33, 6, 1) ELSE 1
Effect on Red Radar Quantity	Effect_on_Red_Radar_Quantity = IADS_Installations*SOF_Kinetic_Strike_on_Red_RADAR
IADS Installations	<GHOST Function, See Stock Equation from Stock and Flow, Diagram 1A>
Red Radar Coverage Area	Red_Radar_Coverage_Area = Red_Radar_Range*Red_Radar_Range*3.14*Effect_on_Red_Radar_Quantity

Red Radar Range	Red_Radar_Range = 300 (current state, adjusted to show effect of different ranges) UNITS: Kilometers
Red Radar Coverage Density	Red_Radar_Coverage_Density = Red_Radar_Coverage_Area/Area_of_Operations_Size
Area of Operations Size	Area_of_Operations_Size = 185000 UNITS: Square Kilometers
Red SAM Battlespace Coverage	Red_SAM_Battlespace_Coverage = Red_SAM_Coverage_Area/Area_of_Operations_Size UNITS: Kilometers
Red SAM Coverage Area	Red_SAM_Coverage_Area = Red_SAM_Range*Red_SAM_Range*3.14*Red_SAM_Quantity
Red SAM Range	Red_SAM_Range = 300 (current state, adjusted to show effect of different ranges)
Red SAM Quantity	Red_SAM_Quantity = 4 (current state, adjusted to show effect of different quantities)
Red SAM Available Ammunition	Red_SAM_Available_Ammunition = Red_SAM_Magazine_Size*Red_SAM_Quantity
Red SAM Magazine Size	Red_SAM_Magazine_Size = 4 (current state, adjusted to show effect of different magazine sizes)
RED Kill Chain, Diagram 1D	
Red Potential Targets	Red_Potential_Targets = Blue_Strike_Package*Red_Radar_Coverage_Density*.65
Red Fixed Targets	Red_Fixed_Targets = DELAY(Red_Potential_Targets*.75, .0003, 0)
Red Tracked Targets	Red_Tracked_Targets = DELAY(Red_Fixed_Targets*.8, .00014, 0)
Red Quality Targets	Red_Quality_Targets = DELAY(Red_Tracked_Targets*.9, 0.00005, 0)
Red Engagements	Red_Engagements = IN(Red_Quality_Targets*Red_SAM_Battlespace_Coverage, Red_SAM_Available_Ammunition)
Model Settings	
Start Time	1
Stop Time	25
DT	1/1
Sim Duration	1.5
Time Units	Days
Integration Method	Euler

Table 1: Appendix 1, Model Equations

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LIST OF REFERENCES

Adams, Thomas K. "US Special Operations Forces in Action: The Challenge of Unconventional Warfare." Abingdon-on-Thames, UK: Routledge, 1998.

Adee, Sally. "The Hunt for the Kill Switch." *IEEE Spectrum* 45, no. 5 (2008): 34-39.

"All Missiles Great and Small: Russia Seeks Out Every Niche." *Jane's International Defense Review* 47, no. 9 (2014).

Andress, Jason, and Steven Winterfield. *Cyber Warfare: Techniques, Tactics, and Tools for Security Practicioners*. Elsevier, 2013.

Army-technology.com. "S-400 Triumph Air Defense Missile System, Russia," n.d. www.army-technology.com/projects/s-400-triumph-airdefence-system.

Bass, Warren. *A Surpise Out of Zion?* Santa Monica, CA: RAND Corporation. Accessed February 12, 2019. https://www.jstor.org/stable/10.7249/j.ctt19w73b6.10.

Boyle, Darren. "Putin Rolls Out the Big Guns." *Daily Mail*, November 12, 2015. www.dailymail.co.uk/news/article-33116195/Vladimir-Putindeploys-advanced-Growler-antiaircraft-missile-Syria-able-hit-jetsaltitude-90-000-feet-far-away-Tel-Aviv.html.

Brailey, Malcom. *The Transformation of Special Operations Forces in Contemporary Conflict*. Land Warfare Studies Centre, 2005.

Brungess, James R. *Setting the Context: Suppression of Enemy Air Defenses and Joint Warfighting in an Uncertain World*. Washington, DC: US Government Printing Office, 1994.

Cohen, Fred. "Simulating Cyber Attacks, Defenses, and Consequences." *Fred Cohen and Associates*, March 1999. http://all.net/journal/ntb/simulate/simulate.html.

Cordesman, Anthony H., and Abraham R. Wagner. *The Lessons of Modern War*. Vol. IV: The Gulf War. Boulder, CO: Westview Press Inc, 1996.

Creveld, Martin Van. *Air Power and Maneuver Warfare*. Maxwell Air Force Base, AL: Air University Press, 1994.

Davies, Peter. *F-105 Wild Weasel vs SA-2 "GUIDELINE" SAM: Vietnam 1965-1973*. Oxford, UK: Osprey Publishing, 2011.

Davis, Larry. *Wild Weasel: The SAM Suppression Story*. Vietnam Studies Group 6042. Carrollton, TX: Squadron/Signal Publications, 1986.

Douhet, Guilio. *Command of the Air*. Washington, DC: Coward-McCann Inc, 1942.

Eisenstadt, Michael. "Iran's Lengthening Cyber Shadow." *Washington Institute for Near East Policy*, no. 34 (July 2016). www.washingtoninstitute.org.

Evera, Stephen Van. "Offense, Defense, and the Causes of War." *International Security* 22, no. 4 (1998): 5-43.

Finkel, Meir. *On Flexibility: Recovery from Technological and Doctrinal Surprise on the Battlefield*. Stanford: Stanford University Press, 2011.

Follath, Eric, and Holger Stark. "The Story of Operation Orchard: How Israel Destroyed Syria's Al Kibar Nuclear Reactor." *Spiegel Online*, November 2, 2009. http://www.spiegel.de/international/world/0,1518,druck-658663.

Fontaine, Richard, and Julianne C. Smith. "Anti-Access/Area Denial Isn't Just for Asia Anymore." *Defense One* 2 (n.d.). www.defenseone.com/ideas/2015/04/anti-accessareadenial-isnt-just-asia-anymore/109108.

Fruhling, Stephen, and Guillaume Lasconjarias. "NATO, A2AD and the Kaliningrad Challenge." *Survival* 58, no. 2 (2016): 95-116.

Fulghum, David, Robert Wall, and Amy butler. "Cyber-Combat's First Shot." *Aviation Week and Space Technology* 167, no. 21 (2007): 28.

Gray, Colin. *Explorations in Strategy*. Westport, Connecticut: Greenwood Press, 2018.

Hampton, Dan. *The Hunter Killers: The Extraordinary Story of the First Wild Weasels, the Band of Maverick Aviators Who Flew the Most Dangerous Missions of the Vietnam War*. New York, NY: HarperCollins, 2015.

Hart, Liddell. *Strategy of the Indirect Approach*. London: Faber and Faber Limited, 1941.

Hutchins, Eric, Michael Cloppert, and Rohan Amin. "Intelligence-Driven Computer Network Defense Informed by Analysis of Adversary Campaigns and Intrusion Kill Chains." *Lockheed Martin Corporation*, 2009. http://www.lockheedmartin.com/content/dam/lockheed/data/corporate/documents/LM-White-Paper-Intel-Driven-Defense.pdf.

Johnson, Richard. "How Russia Fired Missiles at Syria From 1000 Miles Away." *Washington Post*, October 23, 2015. www.washingtonpost.com/graphics/world/russian-cruise-missile.

Lamb, Christopher. "Perspectives on Emerging SOF Roles and Missions." *Special Warfare* 8, no. 3 (1995): 2–9.

Lamb, Christopher, and Tucker, David. *United States Special Operations Forces*. New York, NY: Columbia University Press, 2007.

Locke, Joseph W. *Air Superiority at Red Flag: Mass, Technology, and Winning the Next War*. Maxwell Air Force Base, AL: Air University Press, 2009.

Majumdar, Dave. “American F-22s and B-2 Bombers vs Russia’s S-300 in Syria: Who Wins?” *National Interest*. Accessed December 3, 2018. www.nationalinterest.org/buzz/why-sky-russias-s-400-vs-americas-stealth-f35-and-f-22-who-wins-26791.

Makovsky, David. “The Silent Strike: How Israel Bombed a Syrian Nuclear Installation and Kept It Secret.” *The New Yorker*, September 17, 2012. https://www.newyorker.com/magazine/2012/09/17/the-silent-strike.

Morrison, Scott. “Redefining the Indirect Approach, Defining Special Operations Forces (SOF) Power, and the Global Networking of SOF.” *Journal of Strategic Security*, The Global SOF Network, 7, no. 2 (2014): 48-54.

Parmenter, Robert C. “The Evolution of Preemptive Strikes in Israeli Operational Planning and Future Implications for the Cyber Domain.” Master’s thesis, US Army Command and General Staff College, 2013.

Przemyslaw, Pazdziorek. “Special Forces Transformation in Face of the Contemporary Conflicts Challenges.” *Review of the Air Force Academy* 1 (2016): 47-60.

Pynnoniemi, Katri. “Russia’s Defence Reform: Assessing the Real “Serdyukov Heritage.” In *Briefing Paper 126*. Helsinki: Finnish Institute of International Affairs, 2013.

Quinlin, Shane. “Jam, Bomb, Hack? New U.S. Cyber Capabilities and the Suppression of Enemy Air Defenses.” *Georgetown Security Studies Review*, April 7, 2014. http://georgetownsecuritystudiesreview.org/2014/04/07/jam-bomb-hack-new-u-s-cyber-capabilities-and-the-suppression-of-enemy-air-defenses/.

Raviv, Dan, and Yossi Melman. *Spies Against Armageddon: Inside Israel’s Secret Wars*. Sea Cliff, NY: Levant Books, 2012.

Rid, Thomas. “Cyber War Will Not Take Place.” *Journal of Strategic Studies* 35, no. 1 (2012): 5-32.

Rosenau, William. *Special Operations and Elusive Enemy Ground Targets: Lessons from Vietnam and the Persian Gulf War*. Santa Monica, CA: RAND Corporation, 2001.

Rothstein, Hy. “Less Is More: The Problematic Future of Irregular Warfare in an Era of Collapsing States.” *Third World Quarterly* 28, no. 2 (2007): 275-294.

Rucker, Jeffrey E. "Using Agent-Based Model to Search for Elusive Hiding Targets." Master's thesis, Air Force Institute of Technology, 2006.

"S-300," n.d. http://www.militarytoday.com/missiles/s300p.htm.

Stein, F, and Anders Fjellstedt. "Network Centric Warfare in Western Iraq." Powerpoint Presentation presented at the CRP Conference, San Diego, CA, 2006. www.dodccrp.org/events/2006_CCRTS/html/presentations/026.pdf.

"STELLA (Programing Language)." Accessed April 24, 2019. en.wikepedia.org.

Stillion, John, and David Orletski. "Airbase Vulnerability to Conventional Cruise-Missile and Ballistic-Missile Attacks." Santa Monica, CA: The RAND Corporation, 1999.

Svendsen, Adam DM. *Intelligence Cooperation and the War on Terror: Anglo-American Security Relations After 9/11*. Routledge, 2009.

Szaszdi, Lajos F. "The Club-K: A Deadly 'Pandora's Box' of Cruise Missiles." *Daily Signal*, August 2, 2011. www.dailysignal.com/2011/08/22/the-club-k-a-deadly%E2%80%9Cpandora%E2%80%99sbox%E2%80%9D-of-cruise-missiles/.

Tabansky, Lior, and Isaac Ben Israel. *Cybersecurity in Israel*. SpringerBriefs in Cybersecurity. Cham: Springer, 2015.

Thayer, Carl. "With Russia's Help, Vietnam Adopts A2/AD Strategy." *The Diplomat*, October 8, 2013. thediplomat.com/2013/10/with-russias-help-vietnam-adoptsa2ad-strategy/.

US Department of Defense. "2018 National Defense Strategy," 2018.

———. "Joint Publication 3-01: Countering Air and Missile Threats," May 2, 2018.

Vistica, Gregory L. "Cyberwar and Sabotage." *Newsweek*, May 31, 1999. https://www.newsweek.com/cyberwar-and-sabotage-166534.

Warden, John. *The Air Campaign: Planning for Combat*. Washington, DC: National Defense University Press, 1988.

Wirtz, James. "Counterforce and Theater Missile Defense: Can the Army Use an ASW Approach to the Scud Hunt?" Carlisle Barracks, PA: Army War College Strategic Studies Institute ACN-95009 (1995).

Withington, Thomas. *Wild Weasel Fighter Attack: The Story of the Suppression of Enemy Air Defenses*. South Yorkshire, England: Pen & Sword Aviation, 2008.

Wright, Clifford A. "Israeli War Machine in Lebanon." *Journal of Palestine Studies* 12, no. 2 (1983): 38–53.

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