Spring 2020

Industry Study

Industry Report

Command, Control, Computers, Communications, Intelligence, Surveillance, and Reconnaissance (C4ISR)

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Abstract

ABSTRACT: For the second year, the Eisenhower School (ES) for National Security and Resource Strategy offered Command, Control, Computers Communications, Intelligence, Surveillance and Reconnaissance (C4ISR) as an Industry Study (IS). The global pandemic outbreak of the Coronavirus-19 (COVID-19) in March 2020, resulted in all classroom lessons and field studies shifting to a virtual environment on March 12, 2020, as a result of the Department of Defense (DOD) Stop Movement Order and state mandated stay-at-home self-isolation policies. The specific focus for academic year 2019–2020 was Medium Altitude/Long-Endurance and High Altitude/Long-Endurance (MALE/HALE) Unmanned Aircraft Systems (UAS). The 2018 National Defense Strategy (NDS) outlines the U.S. strategy to compete, deter, and win in a complex security environment that is defined by rapid technological changes, new threats, and the impact of an extended armed conflict on readiness. Further, the NDS asserts that "Maintaining the Department's technological advantage will require changes to industry culture, investment sources, and protection across the National Security Innovation Base." In response to the NDS, the DOD has focused its strategy on rebuilding a more lethal force that is ready to contend with near peer adversaries such as China and Russia. In the area of C4ISR, the 2020 DOD budget request includes $56.84 billion, a 6% increase over 2019. The 2020 budget prioritizes maintenance and research and development to improve the current systems and the development of new technologies.

The problem statement analyzed by the C4ISR IS included: What are the 5–15 year C4ISR challenges perceived by the DOD stakeholders? What is the capability and capacity of the industry to sustain our C4ISR technology advantages and operate in contested environments? And how will acquisition processes adapt to multi-domain operational constructs including agile software development, user-focused design, and system integration? C4ISR is too large a topic to consider over the course of a single semester, the focus narrowed to meet DOD's C4ISR UAS requirements to operate in contested air and cyberspace in an affordable and resilient manner. The report considers the operational threats posed by the Great Power Competition, the Anti-Access and Area Denial (A2/AD) capabilities of China and Russia, and the threats they pose through the export of C4ISR UAS technologies by analyzing the strategic environment, products, market, innovation and policy, business environment, regulations, mobilization and supply chain, and industry security. The central thesis of this report is to adopt the National Military Strategy (NMS) focus on Great Power Competition (GPC), it is imperative the U.S. advance our UAS edge through investment, innovation, and policy reform. This report offers six key recommendations for the DOD to better align funding and policy to achieve the objectives of the National Security Strategy (NSS) and NDS and keep the edge against GPC.

Disclaimer: The Eisenhower School shifted to a virtual classroom on 12 Mar 2020. The adjustment hindered this TS/SCI industry study. Research and analysis were conducted using open source data. The C4ISR team acknowledges classified programs which promote Unmanned Aircraft Systems (UAS) in support of C4ISR are not address in this industry study.

Table 1: C4ISR Seminar Members

C4ISR Seminar Members	
Name	**Organization**
COL Jay Brooke	U.S. Army (USA)
Mr. Mario Documet	Department of Homeland Security (DHS)
COL Rebecca Eggers	USA
LTC Chae Gayles	USA
Lt Col Robert E. Grimmett III	U.S. Air Force (USAF)
CDR Suzanne Hubner	U.S. Navy (USN)
LtCol Kenny Jones	U.S. Marine Corps (USMC)
LTC(P) Alex Leonovich	USA
Mr. Kevin Lynch	National Geospatial-Intelligence Agency (NGA)
Ms. Dana Lynn Myers	National Security Agency (NSA)
Lt Col Eduardo Pires	USAF
Lt Col Patrick Rienzi	USAF
Ms. J. Michelle Schohn	Department of State (DOS)
Lt Col Robert Yates	USAF

Table 2: C4ISR Faculty Members

C4ISR Faculty Members		
Name	**Organization**	**Position**
COL Karen Briggman	USA	IS Faculty
Col Tara Lunardi	USAF	IS Faculty
Dr. Andy Leith	Civilian (CIV)	Industry Analysis Faculty
LTC J. Ryan Moses	USA	Acquisition and Innovation Faculty
Lt Col Martin Poon	USAF	Leadership Faculty

Table 3: Industry Study Outreach and Field Studies

Industry Study Outreach and Field Studies	
Name	**Organization**
Lt Col Bryon McClain	ES Instructor
Dr. Steven Marazita	National Ground Intelligence Center (NGIC)
Maj Gen (R) James Posse	ISR Ideas
LTG (R) Karen Gibson	U.S. Army
Col Stoney Trent	Joint Artificial Intelligence Center
Dr. T.X. Hammes	National Defense University (NDU) Fellow
Joseph Rouge	USAF A2
Danica Starks	Department of Commerce

Industry Study Outreach and Field Studies	
Name	**Organization**
M. Scott “Boot” Hill	Defense Advanced Research Projects Agency (DARPA)
Manfai Fong	Intelligence Advanced Research Projects Activity (IARPA)
Brian Welsh	Amazon Web Services
John Colley	Aurora Flight Science
Dr. Marc N. Viera	Massachusetts Institute of Technology (MIT) Lincoln Laboratory
Fionna Murray	MIT Sloan School of Management Innovation Initiative
Phil Budden	MIT Sloan School of Management Innovation Initiative
Lt Col Jeremiah Sanders	Kessel Run
Devon Blake Samantha Hubner Saleel Huprikar Janiece Marquez Nick Moon Lou Paladino Zachary Schultz	Premise
Scott Rosenbloom	Federal Aviation Administration (FAA) Air Traffic Regulation and Policy
Dr. T.X. Hammes	Joint All-Domain Command and Control (JADC2): The Future C4ISR Enterprise
Thomas Beaudette Pursley “Scuba” Lichen Jason Paxton	General Atomics
Darren Moe	General Atomics Aeronautical Systems, Inc.
MaryAnn Davidson John Hieman Dan Johnson Viji Krishnamurthy Nicholas Smith	Oracle
Lisa Fronczek	Manufacturing USA
Jason Cox Nicole Meyerson Natasha Spackey	AFFOA
Ed Hendricks Emily McGrath	Nextflex
Christopher Bonzagni Matthew Borowski Andrew Musto Zach Walker	Defense Innovation Unit (DIU): Emerging UAS and Autonomous Technologies
Michael Atwood	General Atomics

Industry Study Outreach and Field Studies	
Name	**Organization**
Jon Bye Andrew Coburn John Hancock Sean Storey Barry Trimmer Trevor Woolven	Thales UK
James Scanlan	University of South Hampton
Jean-Pierre Maulny	Institut de Relations Internationales et Stratégiques (IRIS)
Jean-Pierre Devaux	Inostrva

Summary of Recommendations

Investment Recommendations

Recommendation #1

Integrate third offset technology to bolster UAS operability in a degraded environment.

As the DOD seeks to counter revisionists threats and emerging near peer competitors, the continued evolution of the MALE/HALE UAS through third offset strategy technology is essential to ensure the DOD remains postured to operate in an A2/AD environment in direct support of the C4ISR mission.

Recommendation #2

Invest in U.S. industrial base and international partnerships to increase capacity and resiliency of supply chains for UAS.

UAS component supply chains are vulnerable for several reasons since MALE/HALE Unmanned Aerial Vehicles (UAVs) are mostly domestically manufactured, the individual components are less likely to be made in the U.S. and defense contractors often do not have visibility into the tier 3 supply chain of these components. This lack of visibility raises the risk for foreign influence to include theft of intellectual property, critical components, and functions. The U.S. needs partner with industry to address supply chain risk management while investing in the Defense Industrial Base (DIB) and international partnerships to mitigate supply chain vulnerabilities.

Recommendation #3

Develop a Science, Technology, Engineering, and Mathematics (STEM) talent management program to train, recruit and retain talent needed for technical fields including UAS and C4ISR.

The U.S. should develop a STEM Talent Management program to train, recruit, and retain talent in these fields. STEM jobs need to be held in the same regard as professions such as doctors or lawyers to appeal to America's youth. There is a requirement to incentivize schools to include STEM curriculum in the kindergarten to 12th grade (K-12) programs and institute an out-reach or marketing initiative to entice prospects. The program needs to steer STEM talent to fill government jobs by creating on-ramps through vocational, high school and college programs.

Policy Reform Recommendations

Recommendation #4

Reduce UAV Classification to enable trade, innovation, and market responsiveness.

The U.S. is global leader in MALE/HALE UAS markets, yet export controls based on Missile Technology Control Regime (MTCR) and International Traffic and Arms Regulations (ITAR) restrict international sales allowing other countries to enter the market. The U.S. must remove pre-transfer limitations contained in MTCR Class 1 (UAS flying further than 300km and carrying more than 500kg) and execute existing post sale periodic review to ensure compliance to terms of transfer. Additionally, include zero-day faults to remotely disable capabilities if systems are being misused.

Recommendation #5

Replace line of sight (LOS) Federal Aviation Administration (FAA) requirements with existing technologies to realize flight safety, spur innovations and enable U.S. competition by updating FAA regulations

Domestic policy and regulations related to UAVs are stifling innovation and forcing commercial business abroad. The FAA needs to create regulations with a balance between safety and innovation while facilitating public acceptance of commercial drone use and grow the domestic UAS market, create domestic manufacturing, and encourage innovation, The FAA is responsible for efficient and safe use of U.S. airspace; however, its restrictive commercial UAS regulations prohibit technology advancements. Removing the LOS requirement for commercial UASs while ensuring there are requirements in place for flight safety (cameras, collision avoidance systems, sensors, unmanned flight management) will open up UAS applications such as logistics, inspections, delivery of emergency supplies, humanitarian assistance, and allow spin-on/spin-off technologies.

Innovation Recommendation

Recommendation #6

Develop an innovation strategy focused on long-term national security and prosperity objective, establish innovation integrator, and properly resource transformational research and development (R&D).

The third objective in the NDS is to reform the department for greater performance and affordability. Innovation, technology development and a focus on research and development can set a path to achieve this objective. However, DOD and more specifically, the national security innovation base (NSIB) piecemeals direction and guidance from several national strategic documents such as the NSS, NDS, National Defense Authorization Act (NDAA) and specific topic strategies such as the Unmanned Systems Integration Roadmap or the Executive Order on the American Artificial Intelligence (AI) initiative.

Decreased Federal R&D spending and Commercial R&D focused on applied research has failed to transform U.S. R&D effort. The DOD can correct this problem and adequately resource R&D efforts. With the impending defense budget cuts and impacts of COVID-19, this will be a significant challenge. Analyzing manned programs and continuing with night court type budget drills are ways to identify funds for R&D program use. Prioritizing a focus on innovation and R&D funding will help DOD and the U.S. maintain their competitive edge and meet the great power competition challenge.

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Introduction

This is the second year for the Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) Industry Study at the Eisenhower School (ES) for National Security and Resource Strategy. This report was scoped to Unmanned Aircraft Systems (UAS), including the aircraft, control system, data and control links, and technologies used to fuse the data and provide it to the warfighter. This report focuses on U.S. investment, innovation, and policy as applied to technological advancements for medium-altitude long endurance and high-altitude long endurance (MALE/HALE) unmanned aerial vehicles (UAV) used for and supported by military C4ISR systems.

What is C4ISR?

C4ISR systems (Figure 1) allow data to become verifiable information, which becomes usable knowledge and turns into action, as necessary. C4ISR can be further defined by analyzing its major components, Command and Control (C2), Computers and Communications, and Intelligence, Surveillance, and Reconnaissance (ISR). The Department of Defense (DOD) defines C4ISR as "an integrated operational capability which synchronizes and integrates the planning and operation of sensors, assets, and processing, exploitation, and

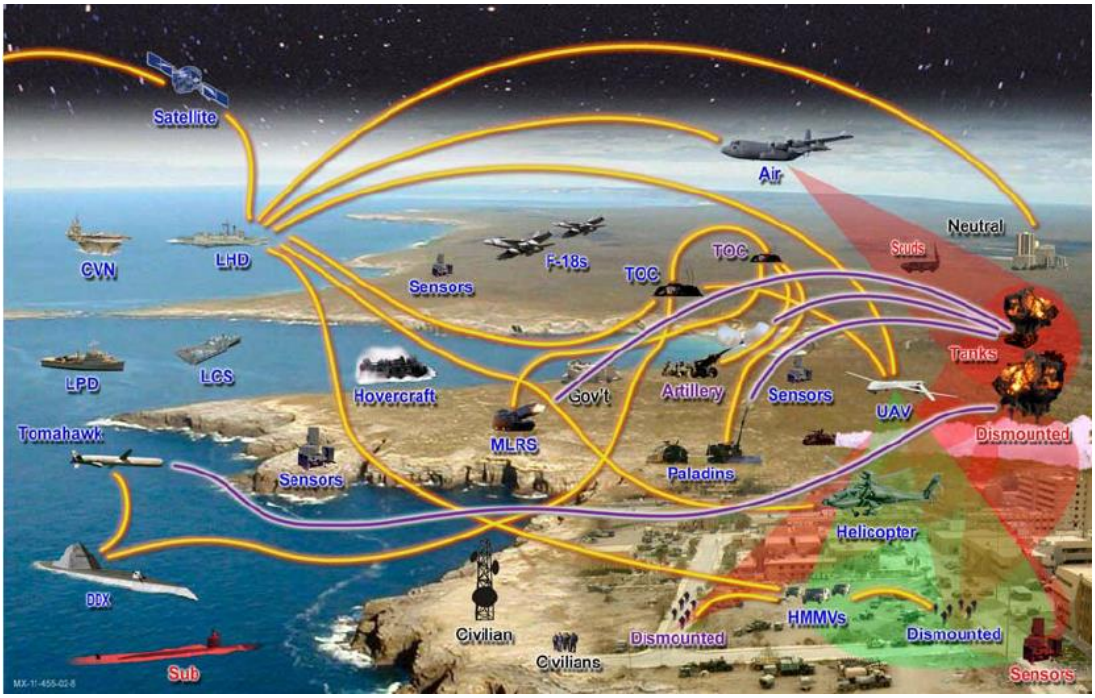

Figure 1: C4ISR Systems

dissemination systems in direct support of current and future operations."[1] The intelligence market comprises strategic and tactical systems and services used to determine enemy order of battle and intentions and to counter enemy intelligence activities. The Surveillance and Reconnaissance entail "strategic and tactical systems that monitor, find, track, and target the enemy while ensuring situational awareness for friendly forces."[2] Together, ISR can be defined as an integrated operation and intelligence activity that synchronizes and integrates the planning and operation of sensors, assets, and processing, exploitation, and dissemination

systems in direct support of current and future operations.[3] The C4ISR is comprised of a broad array of systems, components, platforms, and personnel, which, when integrated, becomes the C4ISR ecosystem.

UAS Defined

Joint Publication 3-30 defines Unmanned Aircraft System (UAS) as a "system whose components include the necessary equipment, network, and personnel to control an unmanned aircraft."[4] UAS are subdivided into 5 groups of unmanned systems (micro, small, tactical, MALE, and HALE) based on performance capabilities (Figure 2). The group 4 and 5 MALE/HALE UAS ecosystem is comprised of communications and data links, unmanned (autonomous or remotely piloted) aircraft, and ground control stations/remote pilot stations provided by the aerospace and defense industry, academia, and government in support of national defense. The focus of this report is the MALE/HALE UAS within the Group 4–5 category, and how they are essential to ensuring the DOD remains postured to operate in an anti-access and aerial denial (A2/AD) environment in direct support of the C4ISR ecosystem and support the U.S. National Defense Strategy (NDS).

Category	Maximum Gross Takeoff Weight (lbs)	Normal Operating Altitude (ft)	Airspeed (knots)
Group 1	0-20	<1,200 AGL*	<100
Group 2	21-55	<3,500	<250
Group 3	<1320	<18,000 MSL**	<250
Group 4	>1320	<18,000	Any airspeed
Group 5	>1320	>18,000	Any airspeed

*AGL = Above Ground Level **MSL = Mean Sea Level

Source: Department of Defense

Figure 2: DOD Classification of Unmanned Systems

C4ISR is too large a topic to consider over the course of a single semester, the focus narrowed to meet DOD's C4ISR UAS requirements to operate in contested air and cyberspace in an affordable and resilient manner. The report carefully considers the operational threats posed by the GPC, the A2/AD capabilities of China and Russia, and the threats they pose through the export of C4ISR UAS technologies by analyzing the strategic environment, products, market, innovation and policy, business environment, regulations, mobilization and supply chain, and industry security. Furthermore, the report analyzes and provides recommendations focusing on the central thesis to adopt the National Military Strategy (NMS) focus on Great Power Competition (GPC), it is imperative the U.S. advance our UAS edge through investment, innovation, and policy reform.

Strategic environment

The DOD has acquired and maintains the most lethal and robust UAS portfolio of any military across the globe. Current UAS capabilities were critical during the past two decades in the two counterinsurgency (COIN) and counterterrorism (CT) conflicts, primarily in the Middle East and Africa, yet the military services face a potential crisis to respond to the near-peer competition in GPC. The U.S. military will face an increased challenge to meet UAS requirements as we transition to the 2017 NDS framework of GPC, specifically the threats of China and Russia as well as continuing threats from Iran, North Korea, and Violent Extremist Organizations (VEOs).

The most recent NSS and NDS highlight the return to great power competition with Russia and China which is a much different operational environment and requirements for UAVs than the relatively low threat areas of the Middle East, Southwest Asia, and Africa that have been a focus since 2001. The UAVs being produced today must be adapted to the A2/AD threat environments that adversaries will most certainly create. The MALE and HALE platforms will need to have some stealth capabilities to penetrate and survive against advanced air defense systems. They will also need to operate with degraded communication links and global positioning satellites (GPS) in a heavily contested electronic warfare environment. This section provides a strengths, weaknesses, opportunities, and threat (SWOT) analysis of U.S. UAV manufacturing while assessing the economic impact, future defense budgets, and the ability of the Defense Industrial Base (DIB) to maintain a competitive advantage in the UAS market

Products

The General Atomics, RQ-1 "Predator" UAS proved invaluable employing electro-optic and video sensors in support of United Nation peacekeeping persistent surveillance operations over the Balkans in 1995.[5] UAS weaponization emerged as the logical evolution while the U.S. adapted to the Post-9/11 battlefields of Afghanistan. The union of a non-kinetic air breathing reconnaissance platform with precision strike munitions offered commanders the distinct advantages, translating offensive power into attack and defense capabilities. As the DOD seeks to counter revisionists threats and emerging near peer competitors,[6] the continued evolution of the UAS, specifically MALE/HALE systems, through third offset strategy technology is essential to ensure the DOD remains postured to operate in an A2/AD environment in direct support of the C4ISR ecosystem and support the U.S. NDS.

C4ISR Market

Funding for UAVs during the past seven years slowed due to declining defense spending, previous purchases of UAV fleets and reduced Middle East operations, however the U.S. continued funding large programs, replacement parts, and research and development (R&D). Although the future market looks promising on the surface, it may experience turbulence. DOD budgets are forecasted to flatten through 2024, and the industry's contribution to society is only expected to reach 1% of gross domestic product (GDP) versus an overall GDP rise of 2.1% (represents declining industry).[7] This reality paired with competing priorities from the COVID-19 pandemic and a growing national debt could impact future UAV and C4ISR markets.

Innovation and Policy Environment

The U.S. is a global leader in innovation, it is in a long-term strategic competition with adversaries like China who are gaining ground quickly and attempting to reduce its security and prosperity through technological advancements. For the U.S. to maintain its competitive advantage, it must advance these technologies by bolstering its national security innovation base (NSIB) with an integrated, focused, and resourced approach. The potential for life-changing, disruptive technology exists within the UAS industry. It does not take a great deal of imagination to envision a future where packages in the commercial and military sectors are delivered by quadcopters and unmanned commercial airliners. It does not take an engineer or entrepreneur to dream of a future where companies such as Uber and Lyft transport customers from their homes to the office or a stadium. It should not take Elon Musk to envision a future where manned military platforms are completely replaced by unmanned strike platforms, reducing American casualties and the higher cost associated with manned aviation platforms.[8] Unfortunately, it seems that the U.S. is missing out on an opportunity to far outpace our allies and adversaries in UAS innovation for reasons that are perhaps rational, but shortsighted and most notably, risk-averse.

Business Environment

Arguably the most important pillar outlined in the NDS is to "Build a more lethal force".[9] The NDS details how the DOD requires a, "Joint Force that possesses decisive advantages for any likely conflict, while remaining proficient across the entire spectrum of conflict."[10] An emerging capability that is on the verge of changing the way we fight in the future is UAV. The unmanned market can quickly get confusing with such an extensive mix of platforms and capabilities, there are many terms that are synonymous with unmanned aircraft. If you further look at this capability from a business perspective, research defines the UAS market as the UAV, a controller on ground, and a communication system between UAV and controller.[11] This section focuses on the use of UASs and how they will play a major role in our ability to maintain a decisive advantage over our adversaries for future operations. To do this the U.S. require a strong defense industrial base with the ability to innovate and a demanding market that continually requires newer technologies on a cyclical basis to maintain a decisive advantage over our adversaries. The purpose of this section is to examine the C4ISR UAS business environment and propose policy or legislative recommendations the U.S. Government can take to harness and protect the NSIB. An evaluation of the Business Environment for this market will be completed along with a comparative analysis of how they are postured to meet U.S. needs going forward with our great power competition with China and Russia.

Trade, Tax, and Regulatory Environment

It has only been in the last decade or so that UAS has truly emerged in the form of civilian, private, and commercial-use remotely piloted aircraft, and that emergence overwhelmed the Federal Aviation Administration (FAA), the federal agency responsible for ensuring the safety of the nation's airways.[12] The mission of the FAA is "to provide the safest, most efficient aerospace system in the world"[13] and the agency's mandate is the regulation of all aspects of the national airspace.[14] The FAA was founded in 1958 as a replacement for the Civil Aeronautics Administration (CAA), but its history goes back further than that. The first attempt at federal regulation of the airways came in 1926 with the Air Commerce Act. Prior to

that, the only regulation of the airspace had come from “common law from state and local court holdings, and statutory law enacted at the state level."[15] The CAA was formed with the Civil Aeronautics Act of that year, and Congress subsequently passed the Federal Aviation Act of 1958 and the Department of Transportation Act of 1966. These Acts reorganized the Bureau of Air Commerce into the FAA, and “despite the changes in name, the scope of agency regulations has remained remarkably consistent and broad.”[16]

Only after appropriate regulations were put in place did the aviation industry really take off. The same is likely true for the UAS industry. “The FAA's history teaches three lessons that may be applied to drones: (1) safety regulation promotes commerce, (2) air traffic management must be consolidated and include more than just visual collision avoidance, and (3) public perception matters.”[17] To that end, the small UAS Aviation Rulemaking Committee (sUAS ARC) was chartered in 2008 “to recommend a comprehensive set of rules that would permit a gradual integration of small unmanned systems into the national airspace under very limited and controlled operating restrictions.”[18]

Mobilization and Supply Chain

In 2017, President Trump issued Executive Order 13806, directing the Secretary of Defense to assess the current state of the DIB. The assessment identified risks in the Aerospace sector supply chain that apply to the UAS ecosystem. The assessment team identified five macro forces driving risk into the DIB, the following two impacting the UAS market the most: Sequestration and Uncertainty of Government Spending and Decline of U.S. Manufacturing Capabilities and Capacity. Additionally, the assessment identified ten risk archetypes that threaten manufacturing and the DIB, the following impacting the UAS market the most: Sole Source, Capacity Constrained Supply Market, Foreign Dependency, and Product Security. Finally, risks explicitly identified to the Aerospace sector, which includes UAS, are “long product/system development timelines, high development and qualification costs, and production limitations.”[19]

Industrial Security

Future use of UAVs is expected to grow with increasing military demands for ISR and unmanned capabilities that realize cost savings while mitigating risk to human life. This growth, coupled with a shift towards network centric warfare, is also driving demand for advanced C4ISR systems capable of managing these units and reducing mission cycle times while rapidly processing massive amounts of data.[20] According to the NSS, “China and Russia [have] begun to reassert their influence...today, they are fielding military capabilities designed to deny America access in times of crisis and to contest its ability to operate freely in commercial zones during peacetime”.[21] The return of the GPC requires future UAVs to operate in contested areas with jamming, anti-UAV and advanced A2/AD. Therefore, U.S. R&D toward advancing UAV technologies (autonomy, hypersonics) must be focused and deliberate to outpace near-peer adversaries.[22]

Strategic Environment

Introduction

Understanding key facets and trends of the UAV industry is important for all military planners and programmers. In doing so, we will examine the current security context, the economic strengths of the market, trends in the defense budget and resulting impacts. We will also look a bit deeper at some of the enablers and products associated with UAVs, beyond just the aircraft itself, and finishing up with a brief characterization of the DIB and implications for UAV production going forward.

Security Context

Though UAVs have been employed by the U.S. military over the past 50 years (Vietnam, Desert Storm, Balkans), it was during the post-9-11 era that they became an integral part of the mission, providing persistent surveillance of terrorist targets, and in some cases, completing the kill chain.[23] Today's security environment is a stark contrast from the one faced two decades ago. The most recent NSS and NDS highlight the return to great power competition with Russia and China which is a much different operational environment and requirements for UAVs than the relatively low threat areas of the Middle East, Southwest Asia, and Africa that have been a focus since 2001. The UAVs being produced today must be adapted to the A2/AD threat environments that adversaries will most certainly create. The MALE and HALE platforms will need to have some stealth capabilities to penetrate and survive against advanced air defense systems. They will also need to operate with degraded communication links and global positioning satellites (GPS) in a heavily contested electronic warfare environment. Finally, they will need to leverage sensors of different types (Multi-intelligence disciplines or Multi-INT), fusing data and disseminating to the warfighter reliably, at speed, against an enemy employing Camouflage, Concealment, and Deception (CCD) techniques. The C4ISR and in turn UAS Industry needs to address the challenges created by the evolving security environment and focus on GPC.

Strengths, Weaknesses, Opportunities, Threats

Using a Strengths, Weaknesses, Opportunities, Threats (SWOT) analysis will identify how well the American UAV manufacturing industry is poised to meet the challenges created by the evolving security environment and focus on GPC (Figure 3).

Strengths	Weaknesses
Autonomous function reduce risk of casualties Less expensive to operate Overall UAV market growth U.S. currently holds technical edge	Defense focus of U.S. UAV market Separation of defense & commercial market FAA regulations Exportation regulation Lack of appropriately skilled workforce
Opportunities	**Threats**
Strong commercial UAV market IRAD increase creating spin-off technologies Expanded uses for UAV (Commercial & Military) Export opportunites with relaxed restrictions	A2AD/Non-permissive environments Declining defense budgets Lack of focus on federal R&D spending China's dominance of commercial UAV market Dependency on foreign-made components Supply chain vulnerabilities

Figure 3: SWOT Analysis

The SWOT analysis identifies several areas to leverage in creating recommendations for the UAS industry in the next 5-15 years. These major themes are utilization of the commercial market and allies/partners, increasing research and development, ensuring a robust, appropriately skilled workforce and policy/regulation reform. It is imperative to recognize trends in the environment, both in funding and products, to maximize the usefulness of the recommendations set forth in this paper.

Economic Outlook

With the surge in the commercial UAS market, the economic outlook for the UAV industry and its implications for military MALE and HALE platforms require an examination of the overall market and focus on the military sector. According to the Bank for International Settlements (BIS), the overall market had a value of $18.8 billion in 2018 and is forecast to reach $34.6 billion by 2029, a compound annual growth rate (CAGR) of 5.94% over a ten year period.[24] In the same way, market volume is expected to increase from 4.5 million items in 2018 to 11.7 million items by the end of 2023. Much of the growth across sectors will be driven by increased demand for UAV applications in energy, utilities, agriculture, retail, and defense ISR. It is important to note that impacts from the COVID-19 crisis were not factored into these figures.

Regional segmentation of the overall UAV market is dominated by North America and the Asia-Pacific, anchored by companies like China's DJI with a market share of commercial drones approaching 70% and General Atomics in the U.S., which produces the MQ-1 Predator and MQ-9 Reaper UAVs, mainstays of the military sector.[25] The U.S. dominates the Beyond Visual Line-of-Sight (BVLOS) market, which consists of the larger military fixed and rotary wing UAVs capable of flying at various altitudes, covering long distances, and performing a multitude of missions, with a market share of 72% in 2018[26] Though the numbers can be somewhat muddied as most industry studies do not specifically isolate defense UAVs, at first glance the market looks extremely promising, potentially doubling in value in five to ten years.

The reality is more nuanced, and considerably less promising for U.S. defense contractors, at least in the short to mid-term.

Defense Budget Trends

The drawdown and withdrawal of U.S. forces from the Middle East as well as increasing budgetary pressures from years of deficit spending and a growing national debt will most likely force a defense budget contraction. The Congressional Budget Office (CBO) forecasts a decrease of three percent in 2021, which would translate to about $22 billion when applied to the 2020 defense budget of $738 billion. This is clearly a downward trend. Yet when considering the Coronavirus (COVID-19) pandemic and its impacts on the economy, as well as the possibility of a new administration, it appears the trend will create a volatile market for C4ISR MALE/HALE UAVs and their components, in the mid-term. These downward pressures will have consequences for U.S. UAV manufacturers, as 72% of their revenue come from DOD orders. Industry studies foresee a decline of as much as 10% to 20% in revenues during the FYDP.[27] For some companies, like Northrop Grumman, who produce Global Hawks and Tritons at roughly a $100 million-plus per unit, those declines are already being felt. The 2020 budget proposal from the Air Force includes plans to retire 24 Block 20/30 RQ-4 Global Hawks, while the Navy looks to suspend acquisition of the MQ-4C Triton for two years.[28] Looking outward beyond DOD and the U.S. market may not prove to be any better for Northrop Grumman. Germany, for example, cancelled a $2.5 billion contract for Tritons, citing their inability to meet European airspace safety standards by 2025.[29]

Industry Product Trends

Analysis indicates UAV market will expand significantly in the next five to ten years, though mostly in the commercial sector. Less clear in some of these projections, however, is the trends of the many enablers and products tied to the UAV industry, especially C4ISR. Many industry studies do not break out the costs and value of the products and components used by C4ISR UAVs as part of the Processing, Exploitation, and Dissemination (PED) enterprise.

The focus on the aircraft themselves omits the many components which enable the aircraft to fly and conduct its mission: ground control nodes, communication links, airspace management, sensors, and PED, to name a few. Many of these other components are set to grow dramatically as well, even outpacing aircraft in some cases. According to one study, cameras mounted on UAVs will grow nearly tenfold in ten years. Synthetic Aperture Radars (SAR), which allow imaging of target areas through cloud cover, will grow even more during the same period, from 14,000 to over 175,000 units delivered. Similar trends are forecast for other UAV sensors, communication systems, autopilot components, and sense and avoid systems.[30]

PED, which has become shorthand for the processing and analysis of the volumes of data C4ISR MALE/HALE UAVs produced, is of concern for the field. UAVs have flown an untold number of hours and collected even more data. By 2013, for instance, the MQ-1 Predator and MQ-9 Reaper alone had amassed two million flight hours. The critical fact in this metric is it took 16 years for the UAV community to reach 1 million hours and a mere two and a half years to double those flight hours.[31] The data collected by these type of platforms have reached a staggering volume, to the point that it is impossible to process the amount of data. As UAV numbers, sensor capacity, and aircraft endurance all increase, those numbers will

only grow as noted "the next generation of wide-area motion imagery sensors will be capable of collecting 2.2 petabytes per day, bringing 450 percent more data into the network than all of Facebook adds on a typical day."[32]

The burden of making sense of all this data for the warfighter is not cheap, falling to service PED nodes, like the Air Force's billion dollar Distributed Common Ground System (DCGS) and the Army, with its own version of DCGS at $2.3 billion.[33] Running out of manpower and money as a solution to the growing mountain of data, DOD is turning to innovations such as Artificial Intelligence (AI), machine learning, and data analytics, as viable solutions. To that end, the Air Force's controversial Project Maven got $93 million last year, though it pales in comparison to the $885 million awarded to Booz Allen Hamilton for AI applications.[34] Under today's budgetary pressures, these are significant dollar amounts, and PED will find itself competing for C4ISR defense dollars with the other required components and enablers of the UAV industry even as the overall market grows. The tipping point for a balance between gathering more data and processing the volume of that data becomes critical.

Defense Industrial Base

UAV manufacturing relies on a DIB that is drastically different from its peak at the end of World War II. For example, in the commercial sector, what had once been hundreds of companies supplying the U.S. military has been reduced to a half-dozen large defense contractors who provide 66.3% of the defense UAVs, while the remaining 33.7% of the market is taken up by other smaller firms.[35] Certainly, many of these larger companies will be able to weather the coming market volatility as they are diversified enough in sectors other than UAVs, but some of the smaller firms, who tend to be the most innovative, may not be so fortunate.

The growth in the UAV market will require a robust and sizable skilled labor to ensure the continued health of the DIB overall and UAV manufacturers specifically. The vital nature of this trend is so worrisome that the National Defense Industrial Association (NDIA), in its most recent assessment of the DIB, gave it an overall "C" grade. The assessment noted that the skills and security requirements for the modern labor force causes a severe shortage of labor and results in increased government cost and inability of industry to deliver contracted goods and services.[36] This "shrinking pool of knowledgeable and qualified experts on both the government and commercial sides of the defense industry" is evident from Department of Labor statistics which, as of 2017, considered the U.S. "short almost 12,000 industrial engineers and almost 3.2 million skilled laborers". [37]

Beyond the issues associated with finding skilled labor, there are issues with the supply chain that UAV manufacturers rely on. As noted in the NSS, "Today, we rely on single domestic sources for some products and foreign supply chains for others, and we face the possibility of not being able to produce specialized components for the military at home."[38] The fragility of the foreign-bound supply chain to a myriad of outside factors is currently being illustrated by the widespread impacts of the coronavirus. Historical examples include the need for Joint Direct Attack Munitions (JDAM) during the Iraq War in 2003. Some of the necessary parts came from a Swiss manufacturer, which refused shipment due to opposition to the U.S. invasion, forcing Boeing to procure alternatives at two times the cost.[39]

Finally, the market value of the DIB is increasingly at risk from more deliberate actions, as evidenced by intellectual property (IP) theft, especially in cyberspace. The NDIA in its assessment remarked with concern:

> *Modern defense supply chains rely on sharing sensitive information across cyberspace to coordinate production. More cyber vulnerabilities within information systems mean more security breaches. Ultimately, industry will incur significant costs to protect itself from this threat…industry—particularly businesses categorized within the lower tiers of defense suppliers—already struggles to absorb complex cybersecurity regulations and requirements.*[40]

The above notwithstanding, the U.S. still holds an enviable position, despite the vulnerabilities of the DIB and its manufacture of MALE/HALE UAVs. It has the largest and best trained military in the world, spending "almost as much as the next eight countries combined".[41] In fact, against the backdrop of the renewed "great power competition" framed in the NSS, the U.S. spends more than two and a half times than China on defense. Dollars and numbers aside, the U.S. maintains a demonstrated technological advantage over its nearest competitors, though the gap is closing. It also retains the world's largest and most innovative manufacturing base. It will need to leverage all those early advantages, though, as competitors like China expand their prowess in the UAV sector, challenging both U.S. competitiveness and national security.

Summary

As we have seen, the strategic environment for C4ISR MALE/HALE UAS is fraught with opportunities and risk along with great potential for future (though likely volatile) growth. The strengths and weaknesses of the sector, along with the U.S. drawdown in the Middle East and attending budgetary pressures, will make for a bit of a roller coaster effect for defense contractors in the near to -mid-term, but they appear overall to be poised to endure the headwinds. DOD, along with the firms it relies upon, will also need to balance their resources and allocation against the enablers and products inherent to the C4ISR UAV sector. Reams of data are useless if they cannot be evaluated and fleets of UAVs are grounded if they cannot operate safely in airspace. The DIB supporting U.S. manufacture of UAVs is strong, but has significant challenges from competitors, its supply chains, and from intellectual property theft. How well it rises to the occasion will have profound implications for the U.S. economy and more importantly, national security.

Products

Introduction

The C4ISR ecosystem is supported by various industries and a multitude of technologies. One such technology is UAS, synonymously referred to as drones or UAV.[42] UAS are a critical force multiplier providing time sensitive and actionable ISR to the command and control decision makers. The UAS ecosystem is comprised of three major elements: communications and/or datalinks, ground control stations and/or remote pilot stations, and unmanned (autonomous/remotely piloted) aircraft.[43] To provide clarity, this section will use the term UAS exclusively when making reference the ecosystem in its entirety and will use the term UAV when referencing the air breathing element of the ecosystem. The UAS' three major elements are supported by a myriad of technologies with products manufactured by the aerospace and defense industry.

The DOD categorizes UAS into five (5) groups in accordance to the unmanned aircraft's maximum gross takeoff weight expressed in pounds, normal operating altitude expressed in feet above ground level or mean sea level, and speed expressed in knots indicated airspeed. Group 1 are mini/micro UAS (mUAS), group 2 are small UAS (sUAS), group 3 are Tactical UAS (TUAS), group 4 are MALE UAS, and group 5 are the HALE UAS.[44] Currently, the preponderance of the DOD UAS supporting the C4ISR ecosystem are MALE and HALE systems.

MALE UAS operate between 18,000 feet above ground level (AGL) to 60,000 feet mean sea level (MSL) and remain aloft for extended periods.[45] HALE UAS operate at altitudes above 60,000 feet MSL and can remain aloft for even longer periods.[46] The DOD operates group 4 and group 5 systems in accordance with FAA and International Civil Aviation Organization (ICAO) standards in peace time, national sovereign airspace. UAS operations in military designated airspace is conducted in accordance with the airspace control order of the assigned combatant command.[47] An analysis of U.S. MALE/HALE systems, International MALE/HALE systems, and third off-set technology implications is provided below.

U.S. MALE/HALE Systems

The preponderance of MALE/HALE UAS procured by the DOD is supplied by the U.S. aerospace and defense industry. From the initial fielding of the RQ-1 "Predator" in 1995 to the continuous combat proven technological improvements to date, U.S. produced MALE/HALE systems are the global UAS benchmark. U.S. exports are facilitated through a stringent Foreign Military Sales (FMS) programs managed in partnership with the Department of State (DOS).[48] The leading U.S. MALE/HALE UAS manufactures are Northrop Grumman, General Atomics, Lockheed Martin, Aurora Flight Science, a subsidiary of The Boeing Company, Navmar Applied Science, and Neany.[49] The major UAS manufactures provide eleven MALE and six HALE systems to the DOD, allies, and partner nations.[50]

The MQ-1 "Predator" is the baseline UAS produced by General Atomics.[51] Manufactured to meet the needs of various customers, the General Atomics' MALE/HALE UAS are fielded in various derivatives. The U.S. Army operates the MQ-1C "Gray Eagle" in both the standard and extended range (ER) versions.[52] The U.S. Air Force operates variations of the MQ-9 "Reaper", "Predator C", and "Guardian" along with Australia, France, Germany, Italy, the Netherlands, Spain, the United Kingdom, and in the near future India. The United

Arab Emirates employs the MQ-1 "Predator XP" to fulfill a portion of her ISR requirements.[53, 54, 55, 56]

Operating BLOS via very-high frequency (VHF), ultra-high frequency (UHF), satellite communications, and data links, the General Atomics' UAS cover a section of territory with excellent loitering endurance while eliminating friendly aircrew exposure to enemy fire or capture. The system functions in both a reconnaissance and an armed reconnaissance role. The UAV operates remotely under the supervision of a three-person team, one pilot and two sensor operators. The UAV is controlled through real-time feeds provided to the pilot situated in the Ground Control Station by a forward-mounted color camera. Sensor operators assess incoming feeds real-time and provide inputs to the UAS collection suite via ground equipment and a satellite-ready component known as the Predator Primary Satellite Link.[57]

The UAV is powered by a single turbocharged engine equipped with a rear-mounted "pusher" propeller. The UAV's payload includes electro-optical/infra-red (EO/IR), TV cameras, synthetic aperture radar/ground moving target indicator (SAR-GMTI), and the Lynx multi-mode sense-and-avoid/all-weather functionality radar sensor. The assorted modular payloads append the UAV as needed in support of real-time and still image reconnaissance and surveillance operations. In the armed reconnaissance role, the UAV is capable of employing precision strike munitions like the AGM-114 Hellfire anti-tank missiles, AIM-92 Stinger short-range air-to-air missiles to combat low-flying enemy aircraft, and various guided bombs such as the GBU-12, GBU-38 series, GBU-44/B Viper Strike series and the Joint Direct Attack Munitions (JDAM) cued with an integrated laser rangefinder that doubles as a laser designator.[58, 59]

To meet FAA and ICAO airworthiness standards for operations in civil airspaces, General Atomics is offering software and hardware upgrades. Features include mitigations against natural dangers such as bird strikes, icing, and lightning in compliance with civil airspace certification. The certification will allow General Atomics' UAVs to legally fly over population centers with the intended goal of monitoring and coordinating civil disaster responses efforts.[60]

An integral C4ISR asset in the USINDOPACOM area of responsibility and proven force multiplier to counter-insurgency operations in Afghanistan, Northrop Grumman's RQ-4 "Global Hawk" and MQ-4 "Triton" are HALE UAS workhorses operated by the U.S. Air Force and U.S. Navy respectively. DOS granted FMS approval for Australia, Germany, Japan, and South Korean acquisition supporting allied and partnership capacity building.[61] However, Germany opted out of the MQ-4 acquisition in January 2020 citing UAV system incompatibility with future ICAO airspace operability requirements.[62] With peace-time airspace interoperability as a known deficiency and a viable out year mitigation strategy, the RQ-4/MQ-4 remains the best HALE UAS on the global market.

The Northrop Grumman HALE UAS features a 32-hour in-flight endurance time providing persistent intelligence gathering, target identification, and general reconnaissance offering ground commanders and war planners precious extended loiter times. The diverse sensor suites provide imagery intelligence (IMINT) with a Raytheon and Hughes integrated SAR and EO/IR package, links fielded forces with rear echelon support via the Battlefield Airborne Communications Node (BACN), and enhances wide-spectrum signal intelligence (SIGINT) with its Airborne Signals Intelligence Payload (ASIP). Naval sensor sets facilitate

over-water Broad Area Maritime Surveillance (BAMS) with the Raytheon developed Multifunction Active Sensor Active, Electronically Steered Array (MFAS AESA) radar suite.[63, 64]

The Global Hawk/Triton UAV ground control station is composed of two entities, the Launch and Recovery Element (LRE) and the Mission Control Element (MCE). A pilot operating form the LRE provides precision differential GPS corrections during takeoff and landings. The UAV operates BLOS autonomously based on preprogrammed flight data. However, mission control teams operating from geographically separated MCEs can provide BLOS navigation updates during mission execution via satellite communications in addition to the transmission of sensor data in support of mission data analysis. The RQ-4 common data link supports direct down link of sensor data when the UAV is within line-of-sight of an associated DCGS.[65]

A mature weapons system and key contributor to the C4ISR ecosystem, the RQ-4's continued service as a front line UAS force offering is being questioned by the U.S. Air Force. Citing high operating cost and limited sensor employment fluidity, the U.S. Air Force is advocating a fleet reduction.[66] The June 2019 shoot down of a Navy RQ-4 variant conducting a surveillance mission over the Gulf of Oman and the Strait of Hormuz by an Iranian surface-to-air missile makes one question the operability of the RQ-4/MQ-4 in an anti-access/area denied environment.[67] With a typical orbit at 60,000 feet MSL and a large radar cross section,[68] the RQ-4/MQ-4 UAV is an easy target for an enemies integrated air defense network.

International MALE/HALE Systems

A sound understanding of the U.S. MALE/HALE industry assists in one's understanding of a nations drive to acquire and/or build an indigenous MALE/HALE UAS. Over the past decade, the UAS industry has exploded with multiple international countries producing MALE/HALE UAS for their nation's defense and export. Identical to the U.S., the international UAS ecosystem is comprised of three major elements: communications and/or datalinks, ground control stations and/or remote pilot stations, and unmanned (autonomous or remotely piloted) aircraft. Second to the U.S., Israel is a major producer and exporter of MALE/HALE UAS.[69] Four companies within the Israeli defense industrial base combine to offer six MALE systems and two HALE systems. Export variants have been sold to Brazil, Chile, Colombia, Mexico, Russia, Switzerland, and Turkey. When combined with Middle Eastern neighbors Turkey which has two companies that produces three MALE systems with exports to Qatar, and the United Arab Emirates which has a single company that produces three MALE and two HALE systems with exports to Nigeria and Russia, the regional export exceeds U.S. MALE system production and falls short of U.S. HALE system production.[70]

In Asia, China dominates the MALE/HALE production market with three companies building nine MALE systems and one HALE system. Chinese export countries include Algeria, Egypt, Iraq, Myanmar, Nigeria, Pakistan, Saudi Aribia, and United Arab Emirates. The European MALE/HALE landscape is shared by France, Italy, and the Netherlands who combine to offer four MALE systems with exports to neighboring European countries and Egypt. The remaining manufactures are Canada and South Africa who have one defense industry MALE manufacture each.[71] Iran and North Korea are believed to possess MALE/HALE systems; however, specifics on Iranian capabilities would indicate two

indigenous MALE systems may exist[72] and there is no data with regard to North Korean MALE/HALE capabilities.

Third Off-set Technology Implications

Current MALE/HALE UAS employ second off-set strategy technology such as electro-optical sensors and global positioning navigation systems.[73] In his address to lawmakers at a House Armed Service Committee hearing to the Subcommittee on Tactical Air and Land Forces, the Honorable William Roper, Assistant Secretary of the Air Force for Acquisition, Technology and Logistics emphasized the importance of incorporating third off-set strategy technology into future procurements, "If we continue to build the same kind of systems and fight the same kind of ways, we're playing to [China's] hands."[74] Specifically, with regards to UAS, Dr. Roper informed the committee, "The Reaper has been a great platform for us. Four million flight hours, just undeniable overmatch in a low-end uncontested fight, and it is certainly saving lives, but as we look to the high-end fight, we just cannot take them into the battlefield. They are easily shot down."[75]

Dr. Roper's sage advice and astute observation coupled with the recent shoot down of the U.S. Navy RQ-4 and cyber infiltration/hi-jacking of the OGA operated RQ-170 by a rogue Iranian regime servers as a reminder of the third off-set strategy technology applicability and the risks associated with status quo UAS operations in an A2/AD environment. During a visit to Amazon Web Services (AWS) this semester, an AWS expert demonstrated their advancements in artificial intelligence/machine learning, a third off-set strategy technology.[76] The AWS representative described how the DOD could incorporate machine learning into a human-machine collaborative decision-making process though the use of a "raspberry pi."[77] Placement of a raspberry pi encoded with autonomous learning algorithms into a UAS' sensor suite enables real-time "on the edge" sensor data analysis. The byproduct is a human-machine collaborative decision-making edge computing process which eliminates superfluous data flow and cues desired sensor data at the speed of relevance for the decision maker.

The edge computing process was discussed at lengths with software engineers from Palantir Defense, a company which specializes in removing technical barriers to ensure better data-driven decision making, during a site visit this semester. From a software engineering purview, edge computing is feasible. The biggest barrier is man's ability to relinquish trust to the data analytics of the machine. Artificial intelligence/machine learning and trust are noted as pillars of autonomy in the DOD Unmanned Systems Integrated Roadmap FY2017 -2042. Trust is the keystone to automated decision-making support in a contested environment. Trust enables unmanned systems data analytics strategies to analyze, fuse, store, and report information.[78]

Equally challenging in a contested environment is access to customary navigation services like GPS. It is assumed the adversary will jam or destroy the GPS constellation and encrypted datalinks supporting UAS operations in an A2/AD environment.[79] An emerging technology which enhances UAS operability in a GPS denied environment is Simultaneous Localization and Mapping (SLAM)[80] presented by Mr. Palmer Luckey, founder of Anduril Industries.

Anduril Industries, an optic technology pioneer, harnesses artificial intelligence and sensor fusion to solve complex national security challenges.[81] SLAM is a basic algorithm used for the creation of a localization and map. Data sets are encoded with GPS and inertial data

during the SLAM localization and mapping process. The belief is SLAM algorithms bolster a UAS' ability to utilize low frame rate data sets typically associated with GPS and inertial data latency. Since MALE/HALE UAS archive GPS and inertial measurement unit (IMU) data while conducting flight operations, SLAM should determine the next frame's pose based on extrapolated GPS and inertial data enabling UAS navigation in a GPS denied environment.[82] Anduril Industries is validating the GPS-SLAM concept of operation in their Ghost small UAS.[83]

Summary

Third off-set strategy technology is the bedrock upon which the future C4ISR ecosystem must be built. In a rapidly changing environment, intelligence, surveillance, and reconnaissance data must be shared while operations are planned across dispersed locations. As the DOD seeks to counter revisionists threats and emerging near peer competitors, the continued evolution of the UAS, specifically MALE/HALE systems, through third offset strategy technology is essential to ensure the DOD remains postured to operate in an A2/AD environment in direct support of the C4ISR mission.

C4ISR Markets

Introduction

The enabling technologies of the Digital-Information Age have the potential to expand the UAV market exponentially and indeed, growth outlook prior to the COVID-19 pandemic was optimistic. Still, in order to truly harness this potential in a commercially viable way, ensure an American comparative advantage in the market, and nurture this sector of the Defense Industrial Base- challenges remain in innovation, legislation, and human capital. It is the best interest of U.S. National Security to nurture this industry and the markets that drive profit for a variety of American firms, particularly in the context of near-peer economic competition.

Porter's Five Forces and the Competitive Spectrum

In order to examine the challenges and opportunities of wide-spread drone employment, this section will examine the market through the lens of "Porter's Five Forces," a widely accepted Harvard Business School model used to determine a firm's competitiveness in an industry through five factors: Threat of New Entrants, Bargaining Power of Suppliers, Bargaining Power of Buyers, Threat of Substitute Products or Services, and rivalry Among Existing Competitors. The model can be applied in a similar manner across the UAV market and consumer, commercial, and security sectors.

Previous analysis of the UAV market from a defense perspective rates the threat of new entrants as low. The current defense business environment lends itself to innovative startups and venture capitalists selling their ideas to the larger firms. A 2018 Price Waterhouse Cooper (PWC) report suggests this may be less accurate than it appears. Citing large innovative firms such as Space-X and including advanced technological initiatives in other countries such as Russia and China, the erstwhile consulting firm points to the Western defense establishment's famously risk averse cultures that often focus more on shareholder dividends at the expense of research and development(R&D), "To keep pace with new entrants, companies must focus on innovation."[84] Because of the innovative focus of these potential new entrants, a challenging force for UAV firms lie in the threat of new substitutes or services in our constantly innovating landscape, and the bargaining power of buyers. Advanced UAVs remain largely dominated by government buyers, with some identifying the market as monopsonist. Still, perhaps the strongest force in this industry remains the level of rivalry among the small number of firms. In the same report, PWC cites recent high visibility mergers and acquisitions such as the 2018 Thales-Gemalto deal as a means of advancing innovation and maintaining market edge[85]- but this can also exacerbate the oligarchic challenge to the market. In fact, the limited number of firms render the market closer to an oligarchy on the competitive spectrum. Expanding the use and public acceptance of drones could move the market toward a more "perfect" competition.

Commercial UAVs

The DOD and by extension, the National Security enterprise, benefits from a stable, profitable UAV industry. It is essential that the UAV industry capitalize on the commercial sector and realize potential applications to maintain healthy competition, profitability, and stability. These market forces can facilitate innovation and ensure sustainability and availability to surge when needed in the interest of National Security. The current outlook for

the industry is strong, in fact, Business Insider Intelligence currently anticipates drone sales to be greater than $12B USD in 2021, a 7 percent increase from 2016, and this is consistent across various market analysis reports.[86] In order to fully illustrate this forecast, however, it is necessary to examine the different sectors in more detail.

The consumer drone, more commonly known as the recreational or hobby drone, is expected to grow 18% to $4.05 billion by 2022, driven in part by photography hobbyists.[87] The domestic market continues to be limited in part by FAA rules (hobby drones must be registered and can only fly up to 400 feet) and privacy/property concerns. This is isolated in part to the U.S., since the FAA has enacted the Low Altitude Authorization and Notification Capability (LAANC) system as part of an effort with industry to ease bureaucratic hurdles., The European Union is expected to further ease restrictions and promote flexible approaches to harnessing the technology.[88] Still, having legalized drones in 2018, some analysts predict India will be the world's largest commercial drone market (in this context "commercial" refers to any drone not used by the State for official purposes) by 2024, behind only the U.S. and China.[89]

Images of autonomous flying transport or Amazon packages instantly delivered to suburban doorsteps by a fixed wing drone are exciting and prototypes for these technologies exist. But drones are already being used extensively in the agriculture, energy, and entertainment industries. According to Allied Market Research, "The global commercial drone market was valued at $2,145 million in 2015, and is projected to reach $10,738 million by 2022, growing at a CAGR of 26.2% from 2016 to 2022."[90] From an FAA perspective, the commercial drone market was expected to triple between 2019 and 2023, faster than previously anticipated.[91]

Agriculture is perhaps the biggest benefactor of commercial drone developments. Currently used for soil and field analysis, planting, crop spraying and monitoring, irrigation and health assessment – drones can be used to "decrease planting costs by 85%."[92] As Manzur contends, users will continue to push for more data, and more accurate data, and in response the agricultural industry will continue to push for "more sophisticated sensors and cameras, as well as look to develop drones that require minimal training and are more automated."[93] Expansion of drone acceptance, alleviation of regulations and availability of infrastructure in the U.S. commercial/enterprise market will increase demand for better, more innovative technologies. These initiatives are necessary to encourage competition and create a "natural" market where the price is set and there is more room for new entrants. This expansion will aid in stabilizing the industrial UAS manufacturing base. Furthermore, the DOD has a proud history of promoting innovation that is adopted by the civilian sector, drone technology may represent a shift where the commercial requirements drive adaptable technology for the DOD. Regardless, healthy market competition is essential to these developments.

Role of U.S. Government

It is essential for the United States Government (USG) to support and nurture this industry, both defense and commercial, for U.S. companies and innovators to profit and thereby continue to develop the leading technologies and maintain (or obtain) a competitive edge. The most powerful driver in the current drone market is the continued growth of the defense, security, and safety markets. Prior to the COVID-19 pandemic, defense budgets of major economies were expected to continue rising, as well as militaries in emerging economies- this was expected to drive a CAGR of 34.7% in the sector from 2019-2027.[94]

As a result of the pandemic, however, the future of defense, indeed, the future of perceived threats and the nature of international competition, are far less clear. Just as PWC recommended against major defense contractors relying on status quo, some analysts suggest that the corporate culture of Boeing, Lockheed Martin, Northrop-Grumman, etc., is a threat to their market shares and they have depended on outsized defense budgets for too long. PWC recommended in 2019 that defense companies adopt, "Agility in the face of market uncertainty through a dynamic strategy process that is not constrained by annual financial-planning cycles."[95] Can the major companies "decouple" from the Iron Triangle and Congressional pressure to continue to provide manufacturing jobs in certain districts and move to innovative technologies?

Constraints

The greatest market constraint across all sectors involves Human Capital, and the need for trained and skilled operators.[96] Competition for the most capable operators and developers will continue to challenge corporations and governments across the industry. In order to move toward a more competitive market and promote an organic U.S. based drone ecosystem, the USG has another role that can be considered part of infrastructure: Promoting Science, Technology, Math and Engineering (STEM) education and degrees. Moving from the Defense Industrial Base toward a National Security Innovation Base[97] could not only ensure American warfighting superiority but develop the UAV market with the U.S. in the lead and cementing American dominance through the Economic tool of National security.

Emerging Markets

With the continued proliferation of smart phones and easier access to enabling technologies , emerging economies may represent additional market opportunities.[98] In fact, these societies may represent an option for U.S. philanthropic, economic, and diplomatic efforts to counter Chinese influence in certain parts of the world, and at a reasonable cost. The British Broadcasting Company recently reported on drone use in Africa and in particular, on Lifebank, a blood delivery company in Nigeria and the potential use of drones on the vast and varied continent.[99] In countries that are being further stripped of their natural resources in the modern era, the technology of drone operation and manufacturing is considered a possible avenue for increasing GDP and alleviating poverty. As the World Bank's Edward Anderson recently stated, "Rwanda is one of the most densely populated rural parts of the world. In the long run we're looking at drones providing economic opportunity in agriculture, for small-scale manufacturers, and to deliver time-sensitive goods such as cash and documents."[100] Africa may be an ideal investment for U.S. drone manufacturers with encouragement from the USG. Building strong stable societies and additional trading partners are of long-term benefit to the U.S. and countering Chinese influence in the area, while benefiting from a new source of intellectual exchange, or potential Human Capital, would only be a positive development in the interest of National Security.

Chinese Competition and Intellectual Property Concerns

Still, who manufactures these drones? China's Shenzhen based Daijang Innovations (DJI) remains the world's biggest supplier of consumer drones with 70% of the market share. In September 2019, The American Drone and Security Act was proposed by a bipartisan group

of Senators, prohibiting Federal agencies from purchasing drones or drone technology from China, as stated by Senator Marco Rubio (R-FL):

> *"American taxpayer dollars should not go to state-directed or state-owned companies used by China to undermine U.S. and foreign competition, especially in critical industries that are vital to U.S. national security. Chinese companies routinely steal and provide information to Beijing's military and intelligence apparatus, and DHS recently warned of the threat posed by Chinese-manufactured unmanned aerial systems and components. The American Security Drone Act seeks to protect U.S. national security and ensure taxpayer funds are not being used to buy drones from companies backed by the Chinese Communist Party and other foreign adversaries."*[101]

In October of the same year, the Department of Interior grounded its entire fleet of 810 drones while it assessed security implications.[102] The Act, however, applies only to provisions by the Federal Government. As the public debate over Chinese technology intensifies, and legitimate concerns are compounded by COVID-19 induced xenophobia, the use of drones by municipalities may engender greater anti-Chinese sentiment – and additional resistance to drone usage based on privacy, civil liberty concerns and what is perhaps a natural resistance to change. Elizabeth, New Jersey has instituted drones to monitor public spaces and enforce social distancing mandates.[103] It is necessary to balance any debate and ensure that the positive applications of drones, autonomous technology, and other emerging technologies do not get lost or exploited in ideological arguments of larger scale.

While the political debate and motivations about denying Chinese technology and curbing Intellectual Property theft continues, DJI remains the world's largest manufacturer of commercial UAVs. As the world turns increasingly away from globalization and free trade, the trend being exacerbated by the COVID-19 pandemic and limitations of supply chains, it is increasingly important to promote innovation and develop the capacity to manufacture these technologies in the U.S. countering geopolitical rivals and competitors. As a policy recommendation, the Act could go further to promote domestic innovation, experimentation, and infrastructure development to include pressure on the FAA to progress in establishing safe and enforceable laws to promote the technology.

The rush to modern isolationism is not unique to the U.S. but it is necessary to retain trusted relationships with our closest partners to advance defense interests and leverage the innovation of allied nations. In reference to China's push to dominate technologically advanced products, Neil Irwin writes in the New Yok Times, "(This) has made Americans, Europeans and the Japanese all the more reluctant to have major operations in China, for fear of intellectual property theft."[104] In addition, as refenced by Professor Jim Scanlan, the United Kingdom's exit from the European Union (BREXIT) presents roadblocks to funding and cooperation in the development of new products and systems to compete with DJI and other companies. Decoupling from China can be balanced with strategic thought towards increased cooperation with trusted allies.

Summary

What remains constant, however, is the need for the Department of Defense to maintain a robust Industrial Base and technological edge. The necessary adaption of UAVs and emerging technologies into the arsenal requires the government to look beyond the Prime

defense contractors and leverage the work of smaller firms. To keep these firms solvent and innovating, they must be able to compete in a stable market and against Chinese state backed companies such as DJI. American society stands to benefit greatly through the advancement of UAVs and government intervention to build necessary infrastructure, advance understanding and acceptance and lessen the regulatory burdens are vital to a healthy industry that can not only redefine modern warfare but also be poised to surge in kinetic hostilities on a large scale.

Innovation and Policy Environment

Introduction

The U.S. must prepare for a 21st century contested war against a formidable adversary such as China, where it will be threatened by advanced cyberspace attacks and anti-access capabilities. The NSS says "the U.S. must regain the element of surprise and field new technologies at the pace of modern industry. Government agencies must shift from an archaic R&D process to an approach that rewards rapid fielding and risk taking."[105] Simply put, the U.S. must invest in the future today by strengthening the NSIB, so its warfighters have the competitive advantage to fight tomorrow.[106]

Global Innovation and Country Analysis

Amidst competing global priorities, innovation efforts are prevailing around the world. According to the 2019 Global Innovation Index (GII), "Global R&D expenditures are growing faster than the global economy and doubled between 1996 and 2016." [107] And although economic growth and public R&D are slowing, innovation forecasts appear resilient. The figure below compares the innovation rankings and strengths of key UAV producing countries (Figure 4).

Nation	Rank	Expectations	GDP %	Notable Strengths
US	3	Above	>2	#1 innovation quality, most S&T clusters, quantity, universities, publications
UK	5	Above	>2	Innovation quantity, universities, publications, environmental performance
China	14	Above	>2	Patents, designs, trademarks, tech exports *Only middle-income economy in top 30
France	16	Below	>2	#5 in VC deals & gaining ground in knowledge / technology outputs
Russia	41	Below	<1	University quality & increasing innovation foundation for future improvements

Figure 4: Global Innovation Index Rankings

Overall, the U.S., China, France, and the UK are investing in innovation and have spent more than 2% GDP since 2013; however, Russia is only averaging 1% and declining.[108] The U.S. and UK performed well in innovation quantity, but China realized similar results with less input. And although the U.S. has the most S&T clusters (26), China's Shenzhen, Hong Kong outperformed the U.S. finishing 2nd behind Tokyo.[109]

According to the NSS, "The NSIB is the American network of knowledge, capabilities, and people…that turns ideas into innovations, transforms discoveries into successful commercial products and companies, and protects and enhances the American way of life."[110] The NSIB and U.S. innovation ecosystem include a diverse set of segments, including national agencies, organizations and labs, Federally Funded Research & Development Centers (FFRDCs), University-Affiliated Research Centers (UARCs), higher academies, defense "primes", industry, venture capitalists (VCs) and the innovative systems of its allies and partners.[111] The ecosystem is depicted by Venn diagrams to represent organizations joined by interactions and relationships versus a hierarchical, top down structure driven by a specific

organization. Appendix A provides roles and responsibilities of the key organizations within the U.S. national ecosystem.

To better understand the emphasis the U.S. puts on innovation, it is sensible to look at how it resources it. The U.S. spent 2.7% GDP on R&D from 2010-2017, outperforming GDP averages of 2.2%. In 2018, it spent 2.82% GDP; however, the majority of it stemmed from private businesses with only .61% federal funding.[112] Taking a closer look at military UAVs and innovation, in 2018 the DOD spent $6.97B on drones with 51% allocated to RDT&E.[113] And the defense budget for FY20 requested $71.3B for R&D (largest in 20 years), including advancements in autonomy ($1.7B), AI ($.8B), hypersonics ($3.2B) and the largest C4ISR increase in 10 years.[114]

The U.S. has a robust business environment including industry, government, and academia partnerships, commonly referred to as the "Triple Helix", with a culture of collaboration and intellectual property (IP) protections. It also has a strong network of innovation hubs and VCs that typically pursue profitable investments versus basic research.[115] However, it lacks an overall national innovation strategy and integrator (champion) to orchestrate efforts toward American prosperity and national security.

Innovation Policy is intended to directly spur innovation versus simply shaping the environment to facilitate it. The U.S. government is risk averse, unlike other countries, because of concerns with overstepping its capitalist culture. Although existing infrastructure is postured to innovate, federal spending on R&D is anemic as a percentage of GDP and as compared to other countries. For the research that is accomplished, there are several policies in place to facilitate transfer to the commercial sector and grant universities IP rights. While this is positive, direct investments in business are limited to mission related efforts.[116]

The UK contributes more to innovation than any other NATO country (except U.S.) at just over 2% GDP, $48B in 2019 (7th globally) and committed to spend $1T over the next 10 years as part of its new innovation initiative kicked off in 2016.[117] It established a defense innovation unit (DIU) to coordinate all activities across the DOD and restructured defense S&T efforts toward a strategy-driven approach that fosters collaboration with the "Triple Helix" (e.g. Rolls Royce & University of Oxford and IQE plc (semiconductors) partnership with Cardiff Univ).[118] Finally, it is increasing funds to cultivate an environment for small and medium entrepreneurs (SMEs) to perform.

France has consistently spent 2% GDP on R&D over the last 7 years but is slowly declining. It comprises 40% of the European Union's R&D Defense budget and has a growing innovation ecosystem consisting of industry, universities, 71 clusters, 4 AI institutes, 3 Quantum Computing labs and VC initiatives/funds. Their innovation ecosystem is primarily state-controlled, and the defense sector has primes (Thales, Safran, etc.) much like the U.S., which invest primarily in late stage R&D.[119] The government invests in basic research and funds SMEs; however not to the levels needed for transformational results. France struggles with dual use technologies and incentivizing companies to transition from research to commercial use. It is reforming its defense innovation system and created the defense innovation agency to drive innovation efforts.[120]

Russia's federal R&D contribution is more than most countries and accounts for 98% of its total R&D. However, since its private sector's contribution is minuscule compared to most, their overall investment has been 1% GDP since 2013. It has a top-down approach to

innovation through its state-owned enterprises, state-run universities, and state-directed entrepreneurs and risk capital providers which has stifled innovation. It is primarily focused on defense modernization; thus, the Ministry of Defense has set 70% of its national innovation policies. Although Russia has had many innovations over the years (radio, TV, VCR, solar cells, Sputnik), it has struggled to transition them into the commercial sector for economic gain, which explains its sparse copyrights, trademarks, and patents. And although it has a reputable university system, it is not properly integrated into the Triple Helix model to realize synergies, and it has a technical workforce shortage because engineers and scientists fled to neighboring states at the end of the cold war. This helps to explain why it fell behind in indigenous UAV production and had to purchase Israeli built platforms until it could realize organic capabilities. Russia created a 2020 strategy to rejuvenate its national innovation system, which included the development of special economic zones (similar to China's Shenzhen) and facilitation of public partnerships/initiatives to spur innovation.[121]

China shares the same structure as Russia; however, it made innovation a national priority more than 30 years ago and has since adopted capitalist ideals to advance its economy and innovation engine. It is pursuing the "Made in China 2025" goal of becoming a high-tech giant, leading the world in AI research (surpassing the U.S. in 2017) and desires to become the world's leading technological powerhouse by 2030.[122] China increased its R&D spending to realize these objectives (thirtyfold increase from 1991 to 2015) and it is paying off.[123] As mentioned they are a leader in science publications and patents, advanced STEM degrees, and are producing innovation outputs on par with high-income countries like the U.S. with significantly less input. [124]

This comparison has highlighted several strengths and weaknesses among leading UAV production countries. Although the U.S. still holds the innovation high ground, its reduced investment combined with China's deliberate approach and resourcing could result in a shifting of the tide if the U.S. does not change course. According to General John Hyten, VCJCS "If you have an adversary, a competitor, that is going fast and you're going slow, it doesn't matter how far ahead you are. At some point that adversary will catch and pass you."[125]

Issues and Challenges

The U.S. cannot wait for the next war or a Sputnik moment to rally innovation efforts. According to previous Intel CEO, Craig Barrett: "It's a creeping crisis, and it's not something the American psyche responds to well. It's not a Sputnik shot, it's not a tsunami." Award-winning New York Times columnist Thomas Friedman adds, the crisis "involves the steady erosion of America's S&E base…the source of American innovation."[126]

On a macro level, the U.S. lacks a focused innovation effort and overall strategy. Currently the NSIB and organizations within its ecosystem derive their direction from several overarching national strategic documents: National Defense Authorization Act, NSS, Defense Posture Statement, USD Research & Engineering Top Technology Areas, etc. Since the U.S. lacks a unified innovation strategy with prioritized, specific, and measurable goals focused on long-term threats and capabilities, it is unlikely to reach its future objectives. Recommend the U.S. develop an innovation strategy focused on long-term objectives to secure U.S. dominance across a range of prioritized emerging technologies (UAV, Quantum, AI, etc.). It should be coupled with a strategy-to-task action plan mapping efforts from the national security objective

to the appropriate agency along with the R&D effort being accomplished.[127] While it would require significant effort to reach this goal on a macro level, the DOD's unmanned program would only need minor adjustments.

The DOD already has an Unmanned Systems Integrated Roadmap (2017-2042) which outlines the desired future and provides overarching guidance on how to get there. While it provides focus areas (interoperability, autonomy, network security, and human-machine collaboration), it lacks the strategy-to-task detail recommended earlier and would need broadened from a defense-focus to a national plan.[128] Much like the U.S. whole-of-government Artificial Intelligence (AI) strategy, which strives to advance AI technologies to maintain American prosperity and national security.[129] Although this AI strategy is for a specific technology, it provides a great framework to build on.

The current NSIB and innovation ecosystem is loosely coupled and lacks an overall integrator (champion) to synchronize efforts, ensure resourcing and produce an innovation strategy to realize prioritized national objectives.[130] For instance, DARPA/IARPA initiatives are informed by national security objectives, but their efforts are determined internally.[131] Additionally, MIT Lincoln Labs is an FFRDC whose budget is $1B per year, and while its initiatives are tied to national security objectives, they set their own priorities.[132] Finally, many agencies unknowingly work on similar research initiatives because there is not a formal information sharing and collaboration effort.[133]

Recommend the U.S. standup an NSIB integrator to create a whole-of-government innovation strategy with prioritized national objectives; secure proper funding; plant the innovation flag and drive all efforts toward it; facilitate formal collaboration to realize synergies and reduce duplicative efforts; and report progress to ensure accountability and transparency. Proper implementation would close seams and harness efforts to efficiently realize technological superiority.[134]

Most technology breakthroughs since WWII stemmed from federally funded basic R&D efforts in laboratories, universities, and industry. It has been responsible for one-third of U.S. patents including GPS, Google Search Engine, etc.[135] However, the federal share of R&D has decreased since the race to the moon and is at its lowest level in over 60 years.[136] During the same timeframe, commercially driven R&D rose, which appears to compensate for the decrease in federal spending but it also changed the focus from basic to applied research.[137] In 2017, this shift resulted in 17% of U.S. R&D being allocated for basic and 80% for applied research.[138] And of the $6.9B the DOD spent in 2018 on UAVs, only 18 of the 51% allocated to R&D was for basic research.[139] The problem with this shift stems from the purpose of each research type. Basic research realizes comprehensive knowledge for the betterment of society; however, it is costly, time consuming and does not result in a specific product. Whereas applied research focuses on knowledge used for a specific purpose and is often turned into near-term profitable products.[140] Therefore it is understandable why businesses invest in applied versus basic research.

The U.S. is still riding the 20th century technology wave with evolutionary advancements when it should be resourcing new revolutionary discoveries to advance society and national security. The U.S. cannot rely on the commercial sector to pursue these transformational breakthroughs on its own and must incentivize basic research. While a majority of this R&D will take place in universities, there are also commercial opportunities.[141]

The U.S. can increase entrepreneurship through targeted tax cuts and increase investments through VC agencies like InQTel to target companies already pursuing early-stage research aligned with national objectives.[142] These recommendations would take advantage of the plethora of ongoing commercial research and enable the military to onboard capabilities. Finally, the U.S. should expand its investments in the Small Business Innovation Research program to help businesses wade through the development cycle's valley of death to transition basic research into profitable commercial products.[143]

Government policy and regulations related to UAVs are stifling innovation and forcing it abroad. While the U.S. is the global leader in MALE/HALE markets, export controls based on the MTCR and ITAR require Department of State approval and are reducing the available UAV global market.[144] With a volatile defense budget, businesses are hesitant to pour more R&D into these capabilities unless they can realize a sufficient return on investment and compete with countries like China and Israel who are selling UAVs (that resemble re-engineered U.S. systems) to this ripe market (e.g. UAE, Jordan, Egypt and U.S. non-allies).[145] Although President Trump loosened restrictions with the 2018 UAS Export Policy update, MTCR sales are still limited.[146] Recommend reclassifying UAVs within the MTCR and/or further loosening restrictions to spur innovation and enable U.S. competition.

The FAA is responsible for the efficient and safe use of U.S. airspace; however, its restrictive commercial UAV regulations prohibit technology advancements and inadvertently push innovation abroad. The FAA limits flights to daytime, below 400 feet, and within permitted airspace and visual line-of-sight.[147] The line-of-sight requirement hinders many useful commercial UAV applications (logistics, oil & gas inspections) and pushed companies like Amazon and Google abroad. Amazon moved its experimental BVLOS drone delivery system to Canada and Google X is testing its Project Wing delivery platform in Australia. Although the FAA is easing its regulations (slowly) and has a waiver process; it takes up to 6 months for a response, and they have only approved 1% of the first 1200 requests. In fact, it took Amazon over a year to receive an approval, but in the meantime the UAV approved became obsolete, and they stood-up an R&D center in the UK to test their platform.[148] Recommend the FAA replace the line-of-sight requirement with essential/existing technologies to realize flight safety (cameras, collision avoidance systems, sensors, etc.). This consideration would bring innovation back to the homeland and align America with other countries who have already taken this step.

According to President Trump's 2017 Executive Order 1806 Task Force, the U.S. has a shortage of Science, Technology, Engineering, and Management (STEM) professionals, which impacts the NSIB's and commercial sector's ability to innovate in fields such as UAVs and C4ISR.[149] There are several reasons for this shortfall, starting with the U.S.' K-12 education system. Charter, private, home, and state-ran schools take different approaches to education (especially STEM curriculum) and do not afford the government the opportunity to guide students toward depleted careers.[150] Universities are projected to produce 30% of graduates needed to fill highly technical jobs and 80% of those graduates are foreign nationals with limited opportunity to continue working in the U.S..[151] Second, U.S. STEM fields lack diversity thus are not capitalizing on the complete pool of prospects; the current minority workforce demographics are abysmal: 2.2% Latino, 2.7% African American, 3.3% North American Indians & 28% women.[152] Third, private investments in technical training has declined by 33%, which limits opportunities for workforce development.

To overcome these challenges, the U.S. should develop a STEM Talent Management program to train, recruit and retain talent needed for technical fields including UAV and C4ISR. It must incentivize K-12 schools to enhance STEM curriculum and provide tax credits for companies to establish state/industry partnerships to realize training programs with onramps to companies.[153] Also, the U.S. must attract and incentivize foreign talent; recommend Congress and State Department create an innovation visa, so those earning advanced degrees in the U.S. can stay and work in these key fields with a path to citizenship.[154] Furthermore, the DOD could identify internal talent and offer organically developed or commercially available programs to produce STEM professionals. China already does this through their Air Force Engineering University, which provides advanced degrees in Unmanned Aircraft Combat Systems.[155] This coupled with incentive pay would entice and produce skilled workers in STEM fields. And finally, if the U.S. really wants to increase its STEM population, it must provide monetary incentives. It could provide federal funding to grant scholarships, payoff student loans, subsidize starting salaries and offer bonuses.[156] China and Israel already do this today (e.g. Israeli government pays 20% of first year salaries in critical fields).[157]

Amazon and the Federal Aviation Administration

In 2013, Jeff Bezos, the owner of Amazon, introduced the world to the future of drone delivery on the television program 60 Minutes.[158] It should be noted here that in the commercial sector, a UAS is colloquially referred to as a drone. The use of the word drone as a colloquialism for UAS was first coined in 1935 by Navy Commander Delmar Fahrney, relating characteristics of bees to early remote-controlled aircraft.[159] Amazon is a company that is the very definition of a disruptive innovator. It famously began as an online bookseller and is now one of the most valuable companies in the world, selling everything from books to drones. It is doubtful that anyone was surprised when he and his company were one of the first to announce their desire to deliver packages via drone. What was surprising and most pertinent to this paper, is that the FAA proved so adverse to the testing they desired to conduct, that they were forced to conduct their testing in England.[160] Regulators in England first authorized drone testing in 2010, while the FAA did not amend its restrictions to accommodate remotely piloted aircraft until June of 2016.[161]

The most significant regulation preventing innovation, specifically in the case of Amazon, and more broadly with UAS companies is what ultimately led Amazon to England and kept their testing there. As with most regulations, buried deep inside Part 107 of Title 14 of U.S. Code:

> *"(a) With vision that is unaided by any device other than corrective lenses, the remote pilot in command, the visual observer (if one is used), and the person manipulating the flight control of the small unmanned aircraft system must be able to see the unmanned aircraft throughout the entire flight..."*

In the previously mentioned video, filmed seven years ago, Jeff Bezos explained his vision for autonomous drones that flew on a flight path from one grid coordinate to another taking into account collision avoidance and other factors.[162] However, today, years after Amazon submitted their request to the FAA, the FAA has not given any indication of relaxing this portion of the regulation in the near term nor distant future.

Alliance for System Safety of UAS through Research Excellence

The FAA has a Center of Excellence called the Alliance for System Safety of UAS through Research Excellence, (ASSURE). The stated mission "is to provide the Federal Aviation Administration the research they need to quickly, safely and efficiently integrate UAS into our National Airspace System with minimal changes to our current system."[163] The vision statement speaks more broadly to encouraging innovation in the U.S.: "to help the UAS market grow into its multi-billion dollar market potential by conducting research that quickly, safely and effectively get UAS flying alongside manned aircraft around the world."[164] Their website touts their work with twenty-three of the world's top research universities and hundreds of industry partners. However, testing is limited to seven UAS testing sites and the restrictions on visual site by a UAS operator.

In terms of the Federal Government incentivizing UAS research, there is some good news. In a press release on the ASSURE website, Elaine Chao, the U.S. Transportation Secretary, announced the awarding of $2.6 million in grants to universities that are part of the ASSURE program.[165] A public-private partnership that spans academia, industry, and government is encouraging. Public-private partnership is most successful when government supports industry with financial incentives targeted towards objectives that will eventually benefit National Security. In this press release, seventy-five percent of the grant money goes to research projects studying "UAS Safety Case Development, Process Improvement, and Data Collection," which essentially amounts to a collection of data "to inform development of regulatory products."[166] The most antithetical statement to true innovation is a quote in the release from Elaine Chao that the "Department [will] lead[s] the way to chart a course for the safe integration of drones into our national airspace."[167] Neither the Department of Transportation nor the FAA is leading the way; they are stifling innovation.

UAS Innovation in England

While the FAA stubbornly refuses to consider pushing the limits and boundaries of unmanned aviation, England, as noted in the case of Amazon, has clear regulatory authority prescribed by their Civil Aviation Administration (CAA) which allows for BLOS UAS operations. In a paper by the United Kingdom - Robotic and Automated System (UK-RAS) Network, titled Robotic and Autonomous Systems for Resilient Infrastructure, under a section on "Global Strengths and Trends," the U.S. is specifically called out for "restrictions on line of sight and daytime operation" that are "significant barriers to widespread uptake."[168] Unlike the FAA, the CAA has very detailed regulations on BVLOS. It requires that "if the person flying the aircraft is unable to maintain direct unaided visual contact with it while it is airborne, then an alternative method of collision avoidance must be employed in order to ensure that it can still be flown safely."[169] It goes on to describe different authorized methods to safely operate UASs in a BVLOS scenario to include a catch-all, "clear evidence that the intended operation will have 'no aviation threat 'and that the safety of persons and objects on the ground has been properly addressed." That is quite different from the FAA's stubborn refusal to even consider BVLOS in regulation. Similar to the U.S., England has several research projects coordinated between academia and industry.[170] In an interesting twist, the aforementioned UK-RAS Network recommends to the UK Government in its white paper on "Extreme Robotics Environments" that it consider an organization similar to ASSURE to further coordinating research between government, academia, and industry.[171]

UAS Innovation in France

In France, the government invests directly in defense and commercial industry. We will use the Thales Group as an example of how the government of France accomplishes innovation through direct investment. Thales is heavily invested in not only Unmanned Aviation Vehicles, but the whole range of capabilities that fall under the C4ISR umbrella: Digital Identity and Security; Defense and Security; Aerospace, Space, Big Data, Artificial Intelligence, and Cybersecurity. They recently acquired Gemalto, "a global leader in digital identity and security."[172] The significance of Gemalto to UAS is one that is a critical piece of the future of UAS world-wide. Gemalto provides expertise in unmanned traffic management systems (UTM) and UAV-to-UAV identification.[173] Thales is working on almost every element critical to a future of autonomous UAS operations: UTM, cybersecurity, artificial intelligence, data generation from sensors, collision avoidance, etc.[174]

Similar to England, but unlike the U.S., French government regulations allow for the operation of drones beyond line of sight. Two regulations, that when paired together are colloquially referred to as the "Creation and Use Order," delineate scenarios, the applicable one here being Scenario Two (S-2) which is defined as: "Using a drone outside a populated area, where no third party is within the area of operation, within a horizontal distance of no more than one kilometer from the pilot, and not falling within the definition of S-1."[175] Furthermore, a certification of design is required to be obtained from the civilian aviation department of the government with the following details both helpful to the kind of experimentation argued for in this paper:

- The pilot must have access to information on the position and movement of the aircraft in real time, ensuring that it does not go beyond the intended limits of its flight.
- The drone must have an automatic system to prevent it from going beyond the horizontal distance limits of the flight or have an alarm system to warn the pilot when it goes beyond those limits.
- The function to stop propulsion in flight, as required of all drones used for "particular activities," must be independent from the on-board automatic mechanisms that control the aircraft's flight path.
- There must be an on-board system to record the essential parameters of the flight, such as location, altitude, and quality of the control signal, allowing an analysis of the last twenty minutes of flight.[176]

The FAA could certainly learn from French regulations and perhaps even provide the highest compliment one institution of government can pay another, copy them, and follow their lead.

COVID-19 UAS Innovation

Perhaps the greatest moments for innovation come during a crisis. The current Coronavirus (COVID-19) is exactly that kind of moment. It would be useful to contrast the previously discussed intransigence of the FAA and how China is advancing the use of drones to combat the pandemic. In an article on CNET.com "Coronavirus is making touch free shopping a necessity," the author Ben Fox Rubin details recent technologies that have played an outsized role during the COVID-19 pandemic. He quoted one CEO of a tech startup as remarking, "I do believe this is an opportunity, this is a huge event in the world, people are

going to change their behaviors and a lot of things that have struggled for adoption will get a new push."[177] Yet, further down the article in which the possibilities of drone delivery are mentioned, the author caveats the excitement by pointing out that they are "limited in the U.S. by strict regulations." [178] Meanwhile, in China, whether for good or bad, regulations do not hinder innovative uses of drones. On the bad side, widespread reporting has detailed the use of drones to shame Chinese citizens into complying with various aspects of their quarantine.[179] On the positive side, they have used drones to spray disinfectant remotely, deliver samples for medical testing, and to ship commercial goods via UAV.[180] The commercial drone deliveries were not the kind allowed by the FAA, within visual line of sight, they were on long-range routes out to two kilometers; the equivalent of about a mile and a half. Quite obviously, regulations in a communist dictatorship are vastly different from those of representative democracy. Even still, there are times where an authoritative government can be more innovative than a democracy due to the nature of governments.

Summary

Although the U.S. is a global leader in innovation, it is in a long-term strategic competition with adversaries like China who are gaining ground and attempting to reduce America's security and prosperity through technological advancements in areas like UAVs and C4ISR. As discussed, MALE and HALE UAVs are a permanent part of the military's stockpile and demand is increasing for them to play a prominent role in contested environments. This demand paired with commercial applications is driving positive (but turbulent) future growth opportunities for defense and commercial businesses. For the U.S. to capitalize on these opportunities and maintain its competitive advantage with UAVs and innovation, it must advance technologies by bolstering the ecosystem with an integrated, focused, and resourced approach. If synchronized and implemented properly, this will energize the right types of R&D, realize an abundant STEM workforce, and change regulations to bring UAV innovation back to the homeland. These efforts will ensure America is competitive in this market and remains a global innovation leader into the future.

The UAS industry is by no means a mature one in terms of technological advancements and innovation. The possibilities for improving quality of life and pushing the bounds of capability are virtually limitless. Thus, countries must be intentional in their investment in this life-changing technology. The U.S. has shown promise in public-private partnerships, but its regulatory restrictions are short-sighted by almost any metric. England's regulatory environment has brought one of America's groundbreaking companies to their island for testing future capabilities of UAV. France is investing directly in these countries and may have set the standard for rationale regulatory policy. Russia and China have obvious investment advantages, but each has problems, be they innovation challenges or trust issues with the rest of the world. The U.S. is already falling behind China in the production of commercial UAS and its European allies in testing regulations. The FAA must strongly consider a reasonable balance between safety and pushing the outer limits of innovation. DJI's dominance alone is concerning. This may not translate directly to defense, but it certainly has consequences for National Security.

Business Environment

Introduction

When seconds mean the difference between life or death, mission success or failure, having an integrated system of systems as the "backbone of operations,"[181] or as the "foundation of every mission"[182] at your disposal will undoubtedly increase your chances for mission success. Possessing a sustainable, reliable, and survivable C4ISR system, is vital in this continually evolving, fast-paced, and competitive technological world. Countries around the world understand that whoever controls the turmoil typically controls the outcome. For this reason, nations like the U.S. and China are competing to develop C4ISR technologies. This section will focus on the external business environment of C4ISR products, with an emphasis on UAVs and the great power of competition between the U.S. and China.

The GPC might explain why despite the precarious demand for UAVs, industry revenue is "expected to increase at an annualized rate of 6.7 percent to $4.7 billion, including a 3.8% increase in 2019 alone."[183] The FY 2021 DOD funding for C4ISR is $11.9 billion and includes funding for systems such as command centers, communications gear; air traffic control; night vision equipment; cyberspace operations; data processing equipment; fire control systems; other information technology; and related systems. The FY 2021 increases by 17 percent from the previous fiscal year due to the increased awareness of Cyber, Spectrum, Artificial Intelligence, and other emerging technologies from China.[184] To remain profitable and ensure customer satisfaction, U.S. companies involved in C4ISR products should continually adjust their business and innovation strategies, with an eye towards the strengths and weaknesses of the regional UAV business environment (Figure 5), to address the great power of competition.

Region/ Country	Market Share	Strengths	Weaknesses	Opportunities	Threats
US	$12B	• Global tech leaders for (HALE/MALE) • Innovation • Diversified companies	• Export Controls • Reliance on Gov't Spending for revenue	• Foreign Military Sales or Direct Commercial Sales	• Redux in defense spend • Competition • Export restrictions
Europe	$3.96B	• Global business w/minimal reliance on specific country • Diversified companies • Tenured execs >4yrs	• Reliance on Gov't spending • Reliance on suppliers • Limited UAS market	• Supply chain, components, accessories • Compete in emerging markets	• Decline in gov't/defense spending
China	$4.5B	• Funded by government • Access/support for national labs	• Controlled by government • Limited competition • Innovation/tech sharing	• Compete in emerging markets	• Increase in competition • US FMS/DCS • Embargos/ trade restrictions
Global Military UAS Market projected to grow from $21 billion in 2018 to $60 billion in 2029					

Figure 5: UAV Business Environment

UAV development is global. The U.S. and China have been the primary drivers in global UAV technology over the past ten years. However, globalization within the U.S. UAV manufacturing industry is low, as most of the industry's companies are based in the U.S. In the

U.S., UAV industries primarily serve the U.S. military markets, as international trade is minimal and reserved for regulations limiting the trade of military technologies. When it comes to UAVs, China has "Pentagon officials scrambling as China 'sell the hell out of' armed drones to U.S. allies."[185]

China Acquisition and Procurement Overview

China maintains its focus on returning to a position of power and wealth, by continually leveraging its growing economic, diplomatic, and military influence to emerge as the foremost power in the Indo-Pacific region and beyond. China's business environment continues to grow and has ranked among the world's most improved economies, two years in a row. China's Foreign Exchange (FOREX) reserves bounced back in 2019 to about 3.11 trillion USD.[186] China's Foreign Investment Law (FIL) went into effect on January 1, 2020. According to Ye Wie, Deputy Director of Administration, China introduced the FIL as "an opportunity to push forward the system of protection, encouragement, and management of foreign investment."[187] Foreign investments or not, China still prefers domestic products. China's public procurement market is regulated by the Government Procurement Law (GPL) and the Tendering and Bidding Law (TBL). Businesses must have access to local knowledge, consistent stakeholder outreach, and strong internal communications to perform well in China. China's two biggest procurement hurdles are the lack of an effective appeals process and transparency.[188]

Concerning China's defense industry, China looks to surpass the U.S. by utilizing its Civil-Military Initiative (CMI). CMI is a national strategy that incentivizes the Chinese civilian population to enter the defense market. CMI focuses on hardware modernization, education, personnel, investment, infrastructure, and logistics. China's "One Belt, One Road" initiative is a great example of how China is extending its diplomatic, economic, and military clout and expanding its global influence.[189] China is also utilizing arm sales to include the sales of UAVs to support its broader foreign policy goals. China's measures to modernize administration and facilitate trade and large-scale tax and fee cuts have led to the expansion of private-sector imports and exports in both volume and proportion. An 890 billion USD equivalent contribution from the private sector accounted for 41.7 percent of China's total foreign trade in the first half of 2019.[190]

U.S. Acquisition and Procurement Overview

The U.S. is riddled with laws, regulations, and a "back and forth between the executive branch and Congress over acquisition and procurement."[191] The ever-complex defense procurement process in the U.S. is managed by the DOD. Each armed service executes its defense procurement and is supported by procurement offices, such as the Defense Logistics Agency. The Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics is responsible for the oversight of the procurement activities of the various segments of the DOD.[192] As the U.S. tries to figure out ways to accelerate its technological advantage and protect it from Chinese theft and espionage, America's bureaucratic red tape, its grueling defense procurement process, its disinclination to leverage the commercial market, and its lack of skilled labor, leave the U.S. in an innovators' dilemma.

U.S. vs. China Business Culture

Chinese businesspeople do not move at the same hectic pace the U.S. does. Chinese businesspeople dawdle and consider decisions while seeking advice from top state officials.

Chinese businesspeople respect hierarchies, as final decisions are often made at that level, and are more akin to the invisible rules of respect and reverence towards managers. After all, most, if not all, businesses are state-owned. Furthermore, Chinese businesspeople count on personal trust in partner relationships. On the other hand, U.S. businesspeople like to see things in writing and usually will not hesitate to challenge their supervisors in a collaborative environment.[193]

American and Chinese business cultures are largely influenced by the differences in American and Chinese mindsets. For example, Americans place great emphasis on the self and personal identity, while the Chinese focus more on a collective national identity. Moreover, Americans see Chinese negotiators as inefficient, ancillary, and unscrupulous. Conversely, the Chinese view American negotiators as hostile and impersonal.[194] Chinese predatory business practices have deterred some nations from doing business with China. However, those who wisely navigate these perceived unprincipled business practice differences can develop mutually beneficial business relationships. For example, the Chinese have sold large UAV equipment to at least eleven countries, many of which are in the Middle East and Africa. U.S.-allied countries, like Saudi Arabia, simply do not want to wait or deal with the political red tape required to obtain U.S.-made defense products. At the same time, other countries feel they have no choice but to accept Chinese help, as they cannot financially afford to do business with the U.S. Meanwhile, countries like Russia, China, and even Israel are filling the void and continue to challenge the U.S.'s piece of the market for defense equipment sales.[195]

UAV Business Market Analysis

The drawback to future DOD collaboration with small and medium high-technology firms and new start-ups can be summed up to economics. The DOD, as a single buyer, presents an intimidating, highly regulated monopsony market. Cash and growth are essential to the survival of these small and start-up companies. Unlike the large defense primes, small and medium-sized companies, especially start-ups, live in an unpredictable business state, where bankruptcy is an ever-present threat. They often do not have the time and resources to deal with the idiosyncrasies of defense contracting.[196] As a result, many of the smaller companies do not enter the defense market or are acquired by top defense primes, which often comes at the cost of losing their identity and freedom to innovate as easily.

General Atomics

General Atomics (GA) is the only privately held defense company that competes in the C4ISR MALE/HALE UAS market with its MQ-9 Predator and Reaper platforms and Ground Control Stations. The GA chairman and CEO, Neal Blue, owns 80% of the company, while his brother owns the remaining 20%. For this reason, the company is not driven by shareholder or stock motives. Unfortunately for this same reason, they do not publicly provide financial information. GA is highly diversified with 12 affiliated companies that specialize in everything from nuclear fuel cycles, airborne sensors, electronic, wireless, and laser technologies.[197] Their diversity outside of defense does reduce some of the risks associated with defense companies that rely solely on the DOD funding for revenue. The company demonstrated this diversity during the Coronavirus pandemic when one of their affiliates that produces reagents was able to develop a COVID-19 antibody test. The ability to rapidly innovate and mobilize if required allows GA to obtain revenue from other markets if defense spending is reduced. This enables them to survive during financial difficulties and remain postured for future defense contracts.

Weaknesses associated with GA are their size when matched up against other defense companies competing in a highly competitive environment and their lack of a huge global presence. With most of their work in nuclear and UASs, they are controlled by the export control laws like the MTCR, which limits export of UASs. Under the MTCR, countries are limited from exporting unmanned delivery systems capable of carrying a 500-kilogram payload at least 300 kilometers or delivering any type of weapon of mass destruction (chemical, biological, and nuclear attacks). [198] For this reason, exports of their MQ-9 UASs could only be done by Foreign Military Sales with U.S. Government approval. General Atomics recognizes this vulnerability and according to John Hemmerdinger from Flight International, "investing internal funds on products it hopes will compensate for waning sales, including Predator derivatives aimed at foreign military sales (FMS)".[199] Due to specific export controls, GAs primary business will always be completely controlled by the DOD.

Northrop Grumman

Northrop Grumman is one of the top U.S. major defense contractors. The Air, Cyber, Land, Sea, and Space divisions organize the company by the specific domains they support. Their RQ-4 Global Hawk and MQ-4 Triton align under their Air division alongside their popular B-2 and B-21 bombers. The recent acquisition of Orbital ATK provides Northrop Grumman with the ability to capitalize on space and weapons. This could be essential in their integration of SATCOM BLOS UASs. They maintain a global presence with business operations in Australia, Europe, Japan, Middle East, and South Korea.[200] The company has a balanced portfolio of products across all domains. Since it also competes in a monopsony market it is also dependent primarily on government for its revenue. Fortunately, defense spending has been on the rise, so Northrop Grumman as been able to capitalize across its portfolio. Although Northrop Grumman does not have the revenue as some of the larger defense companies, their profit margin of 22% is the highest amongst their competitors.[201]

The company's executive management team have been in their positions for less than three years. The CEO and many of the executives joined the company within the last ten years. Many serving as former executives in other companies. As a major defense contractor, they have the resources to place a strong focus on innovation and development. In 2018, they spent $764 million on innovation and development activities.[202] Northrop Grumman collaborates with research institutes and universities to develop homeland and defense security and advance cyber research and innovation. They also sponsor programs like CyberPatriot to inspire young talent for careers in cybersecurity. Northrop Grumman's weaknesses are their reliance on government spending for their revenue. To address this, they are focused on growing its international sales. In 2018 they were able to increase non-U.S. sales to 15% of total revenue.[203]

Lockheed Martin

Lockheed Martin is one of the top defense contractors in the world. The company is organized by its Aeronautics, Mission and Fire Control, Rotary and Mission Systems, and Space divisions. Within the Aeronautics division is the ISR and Unmanned Systems that contain UASs like Stalker XE. Their Skunkworks division is responsible for their stealth technology unmanned aircraft like the RX-180.[204] Like Northrop Grumman, Lockheed is diversified with a large portfolio that covers all domains of defense. Lockheed's primary source of revenue is with governments. With revenue coming in from large programs like the

F-35 Joint Strike Fighter, Lockheed has continued to remain a major force in the industry, however with only 13% gross profit margin they fall well below the industry average of 20%.[205]

In early 2020, it was announced that their CEO of six years would be stepping down. The new CEO will join a new executive management team with less than 2 years average time in their positions. Unlike Northrop that has an executive management team that held positions outside of the company, Lockheed's executives are primarily developed from within the company. Most executives have been with the company for over 20 years.[206] Lockheed has a strong innovation ecosystem that starts with their hefty commitments to research and development. In 2018, they committed over $1.5 billion to independent research and development (IRAD) investments in hypersonics, laser weapon, multi-domain, cybersecurity, and autonomy.[207] Their Skunkworks division is world renown and responsible for early stealth aircraft. They continue that tradition today with development of classified programs, some of which are unmanned. Additionally, Lockheed has multiple centers that contribute to innovation, such as Lighthouse, a center for innovation located within proximity to Suffolk, VA, with the largest concentration of three and four-star operational commands. Lighthouse offers a resource to government, industry, international partners, and academia. Lockheed also has Advance Technology Centers located throughout the U.S., with over 500 technologists and scientists that collaborate with U.S. government laboratories, universities, tech businesses, and LM colleagues. Lockheed's STELaRLab, their multi-disciplinary R&D facility outside the U.S. Its located in Australia, where they partner with universities to explore hypersonic, autonomy, robotics, and C4ISR. Lockheed Martin acknowledges that one of their weaknesses is its reliance on government spending for their revenue.[208] With active production lines for the F-35, F-16, C-5, and C-130 they are looking to mitigate risks arising from decreases in U.S. defense spending by focusing on international expansion. In FY2019, the U.S. Government accounted for 62.4% of their revenue, followed by international with 36.9%.[209]

With the departure of the UK from the European Union, French companies are postured to capitalize on growth in the European defense market. According to MarketLine, "The French aerospace and defense market is expected to generate total revenues of $37.8 billion in 2018, representing a compound annual growth rate (CAGR) of 4.5% between 2014 and 2018. In comparison, the German and UK markets will grow with CAGRs of 2.6% and 0.5% respectively, over the same period.[210] Companies like Thales and Safran will be able to capitalize on growth of the UAS market as the European Union makes an effort to consolidate requirements to improve their defense.

Safran

Safran is a global business with subsidiaries operating out of U.S., Canada, Brazil, Germany, India, Singapore, and Australia. The company is broken into two divisions: Avionics and Defense Divisions. Safran's primary business is manufacturing engines for civil and defense aircraft. Safran is diversified with operations in navigation systems, helicopter flight controls, and optronics. Under its Land Defense division, they produce the Patroller tactical UAV. A strong diversified portfolio that captures revenue mainly from its global operations has shown consistent increases to their revenue since 2015. In FY2017, over 60% of their revenue came from markets outside Europe. Safran remains highly profitable with a 43% Gross Profit Margin, compared to industry standard of 20%.[211]

The company's chairman has been with the company since 2015. Most of the company's executives have been with the company since 2014. Safran continues to make significant investments in R&D. In FY2018, Safran spent €1.4 billion on R&D, accounting for 7% of the company's revenue.[212] However, investments are focused on new manufacturing technologies such as engine hybridization (for helicopters), additive manufacturing, and digital technologies.[213] Safran has collaborated with U.S. companies like General Electric to develop and produce efficient engines. They have established forums for experts to collaborate on areas like image processing and new-generation tactical drones. Safran's CEO has acknowledged that they must step up innovation, with plans to raise their research and technology budget in 2022.[214] Weakness identified are with their currencies since 60% of their business is conducted out of country and are subjected to currency fluctuations while adding a level of uncontrollable risk to their financial outcomes.[215]

Thales

According to the Thales website, "they offer integrated solutions and equipment for the government, civil and commercial customers in the aeronautics, space, transport, and defense and security markets".[216] The company serves five sectors: Aerospace, Space, Ground Transportations, Digital Identity and Security, Defense and Security. They have contributed to the UAS market with their Watchkeeper UAV and their unmanned traffic management system leveraged on their strong presence as the top worldwide air traffic management developer. The company is widely diversified with businesses in 56 countries.[217] Their main source of revenue is from France, with the UK second. They operate in the U.S. partnering with companies like Raytheon, Northrop Grumman, and Rockwell Collins.[218] However, public government and institutional customers account for 75% of their revenue. Therefore, they have a high reliance on governments for their revenue. Thales has managed to see gradual increases in revenue since 2015. Their gross-margin profit is 25%, higher than the industry average of 20%.[219]

The Thales CEO has been in his position since 2014. Many of the executives have been in their positions for over four years and have promoted from within the company. Thales has shown they are committed to growing by their mergers and acquisitions over the past year. They have acquired companies that specialize in artificial intelligence, digital and communications security, and telecommunications traffic. In FY2018, the company spent €879 million on R&D which accounts for 5.5% of their total sales.[220] Thales has an extensive amount of efforts within the company to promote innovation and currently operates six innovation hubs. Thales Research and Technology laboratories and its conference centers are utilized to conduct research. They have agreements with universities around the world, where they sponsor doctoral students, accounting for more than 150 patents and 200 projects.[221] The CEO acknowledged that to sustain profitable growth over the long term, they must continue to deploy operational performance initiatives and strengthen customer culture while stepping up investments in innovation.[222] Similar to Safran, with such a diversified portfolio across many countries, currency fluctuations can result in inadvertent gains and losses. Also, with 25.7% of ownership by the French State, they are not truly an autonomous business and will be controlled by the French Government.[223]

The Defense Market in Asia is projected to have the highest growth going into 2023.[224] Countries like China and India will have an increased demand for military UAVs. According to BIS Research, the military UAV market in Asia will have the largest share of the market. It is projected to grow to $21 billion in 2029 compared to $111 million for the commercial

market. The Chinese UAV market will remain the largest, growing at a CAGR of 8.6% going from $4 billion in 2019 to $13 billion in 2029.[225] The major MALE/HALE UAS producer in China is the Aviation Industry Corporation.

Aviation Industry Corporation.

They design, develop, and produce aircraft, engines, missiles, airport ground support equipment and aviation products. The company is a massive state-owned enterprise with 100 subsidiaries and 28 listed companies and branches across China.[226] They produce the Wing Loong I UAS, Harrier, SW1 and nighthawk UAVs. As a state-owned enterprise, there is no public information on their financial status. The company's president has been with the AVIC since 2018. They have a mix of executives with experience ranging from four to twelve years. As a state-owned enterprise they are responsible for over 90% of China's design, R&D, manufacturing, experiment, and test flight services.[227] They continue to innovate with its extensive government funded network of 33 research institutes, 9 national labs, 24 nationally accredited enterprise technology centers, and 32 province/ministry level enterprise centers.[228] One weakness is their lack of shared technology. Due to arms embargo imposed by the EU and U.S., for Tiananmen square, they are unable to acquire military hardware from U.S. or Western European countries.[229] In most situations this would be detrimental to a company, however since the Chinese government funds the company they retain the revenue to cover capital expenditures and investments.

Summary

The C4ISR UAS global market is growing due to global uncertainty and on-going regional conflicts. Strong companies exist within Asia, Europe, and the U.S. with the necessary resources to advance the capability. Chinese companies like Aviation Industry Corporation of China, remain postured to grow and offer cheap alternatives to U.S. technology. Chinese state-owned enterprises have the full resources of the government and an infinite amount of funding to succeed. As China continues to operate under this model, they will inevitably have the means to start closing the gap on innovation if the U.S. government reduces defense spending and funding for research and development.

Europe also has demonstrated the ability to develop their own UASs with companies like Safran developing the Euroflir 610 and Thales with their Watchkeeper. Both companies are postured for continued growth and expansion. Their strong global presence and limited reliance on the European economy affords them the opportunity to not be severely impacted by defense spending fluctuations in any one country. In addition, both companies show they are committed to spending on R&D and innovation. With Thales, by far demonstrating they have an extensive ecosystem for innovation with labs, centers and connections with universities and governments.

U.S. companies will continue to be world leaders with the U.S. accounting for over 40% of worldwide defense spending.[230] As the Global UAS market continues to grow major U.S. players like General Atomics, Lockheed Martin and Northrop Grumman will need to invest more in R&D of UAS to advance their capabilities. Currently, General Atomics is the only company with their UAS as their primary platform. Although Lockheed Martin and Northrop Grumman both have C4ISR platforms, they seem to be more interested in developing the UCAV platforms of the future. Uncertainty with future U.S. defense budgets will be the determining factor on how much we continue to advance UAS capability. Budget uncertainty

reduces the amount of commitment defense companies can privately invest in future technologies. U.S. companies have taken the steps to mitigate some of its reliance on U.S. government revenue by investing in foreign opportunities. However, with export control laws and restrictions they will be limited from developing new technology for foreign governments. In July 2018, the Trump administration relaxed conventional arms transfer (CAT) policy to allow sale of UAVs through Direct Commercial Sales and reclassify drones with strike-enabling technology (lasers) as unarmed.[231] While this opens sales of some UAVs, MTCR and the 'Countering America's Adversaries through Sanctions Act' (CAATSA), which imposes new sanctions on Iran, Russia, and North Korea still limit business opportunities and growth for U.S. companies.[232] This could affect international expansion opportunities for defense companies, allowing companies from Europe or China to fill the gap.

Trade, Tax, and Regulatory Environment

Introduction

The long-term DOD investment strategy does not optimally meet current or future warfare environments and changes must be made to better align resources against adversarial threats, the changing character of war, and warfighting capabilities. Through increased UAS investment and trade to strengthen partnerships and alliances, the DOD will be better aligned to address the objectives of the U.S. National Security Strategy (NSS).[233]

The U.S. has long relied on its allies and partners for collective security with information sharing as a foundational exchange. Similarly, the U.S. has not attained its preeminent position as a global leader without providing value in return. As the dynamic and character of war is evolving, the U.S. has technological capability, in the form of UAS, that can be shared with allies and partners to improve geopolitical relationships, improve regional security through real time situation awareness, and improve the depth of relationships through economic interdependencies. It should be increasingly clear that endorsement of the international community to conduct collective response to acts of aggression is the new norm, especially against peer/near peer competitors. Therefore, focusing U.S. approach on allies and partners will have the greatest opportunity to deliver military effectiveness and competitive advantage. This section explores the role regulations and trade play in the development and operation of UAS in the U.S. and abroad.

The Market

Industry growth, though healthy, are slowed by concerns over privacy and the safety of "UAS operations in congested airspace and over populated areas," with a major issue being the need for "the development of sense, detect, and avoid technologies that will provide the same level of collision avoidance as manned aircraft."[234] Those concerns, as well as the hodgepodge of regulations and the means by which they have been enacted are likely part of the reason the U.S. government is still the driving force in the industry. DHS and CBP have operated UAVs for nearly two decades, and as recently as five years ago, the DOD was already "spending over $5 billion per year on UAS, flying in excess of 600,000 hours per year, fielding more than 6,000 air vehicles, and training thousands of pilots and sensor operators."[235] In fact, the "United States military now trains twice as many ground operators for its drones as it does traditional pilots for its military jets."[236]

While forecasts predict strong industry growth in the U.S. and global markets over the next ten years,[237] concerns over privacy and safe operation are not the only issues that could limit UAS market growth. "U.S. export control policies, which classify some UAS as weapons and other protected military technologies under the International Traffic in Arms Regulations (ITAR)"[238] limits the conditions under which UAVs can be exported to international markets. "Under ITAR, some UAS are covered under the U.S. Munitions List (USML), and require an export license approved by the U.S. State Department. UAS are also covered by the MTCR, a voluntary arrangement among 34 member countries to restrict the proliferation of missiles capable of delivering nuclear weapons and chemical and biological weapons, and to prevent terrorists from acquiring missiles (including UAS) capable of delivering weapons of mass destruction. The guidelines of the MTCR carry a 'strong presumption of denial' for export of UAS."[239]

The International Trade Administration (ITA) also notes a number of other difficulties facing the UAS market, including "incomplete legal and regulatory structure to integrate UAS into the national airspace."[240] For example, just 10 percent of the UAS included in the "Unmanned Systems and Robotics Database maintained by the Association for Unmanned Vehicle Systems International (AUVSI) can operate beyond the visual line of sight (BVLOS) of its operator."[241] The technology for BVLOS operations has existed for years, but "under current federal regulations, only the military is permitted to use it. The absence of federal regulation allowing BVLOS operations hinders the full value and benefits that the UAS industry has to offer."[242] To assist in the advancement of BVLOS operations, the UAS community has argued for an FAA rule requiring remote ID, which would allow the tracking and identifying of all UAVs in much the same way as exists for airplanes and is "a crucial next step to gain the confidence of federal defense and security agencies, manned aviation users and the public. With this confidence, UAS can further integrate into the national airspace to perform important BVLOS operations such as inspection of utility rights of way, widespread search-and-rescue missions, and package delivery."[243]

Applications of UAS "aren't limited by technology or imagination; they're only limited by regulations. We need a streamlined regulatory environment that allows for the safe deployment of unmanned systems into our nation's transportation infrastructure so we can begin to reap the full benefits of this technology."[244] While the "benefits and applications of commercial drones are limitless-and the market demand has already been realized across a variety of industries,"[245] imprecision in FAA regulations and enforcement make it a challenging market to enter by those not already among the larger parts of the Defense Industrial Base. UAS "represent a bright spot for the technology-intensive aerospace manufacturing sector, but military and civil government agencies will likely be the predominant customers for an extended period while such systems are integrated" into the national airspace.[246] Obviously, this means "the prudent UAS operator or entrepreneur will consult a seasoned professional before embarking on a potentially costly and fruitless enterprise simply to avoid choosing the wrong path-or choosing no path at all-and trying to operate commercially without appropriate authorization."[247]

UAS Regulations

The U.S. military has become increasingly dependent on UAS as part of C4ISR and the warfighting effort in general. Industry is eager to get in on this multibillion-dollar market that promises even greater growth as commercial applications are realized. However, regulations have not kept up with demand, and a lack of appropriate regulation may actually be hindering industry growth. "Although the technology associated with drones is in the midst of a tidal wave of progress," the rules and regulations governing their use have failed to keep pace.[248] The FAA struggled over the years to integrate UAS into the national airspace, overwhelmed by the sheer volume of new operators and options inundating the market. The lack of a cohesive and sensible set of regulations, along with the means to enforce them, has led to concerns that the widespread use of UAVs aircraft will trigger a collision not of the actual aircraft but of "disparate legal principles and maxims."[249] The FAA recently, however, "developed plans to allow for increasingly complex operations, including operations over people and beyond visual-line-of-sight and–eventually–passenger operations."[250]

It was not until 2007 that the FAA "took its first step in what would eventually become the herculean task of regulating drones in the National Airspace System by publishing a notice

of policy that was intended to outline a then-current regulation of unmanned aircraft operation."[251] This notice, a National Proposal of Rule-Making (NPRM), was where the FAA divided drones into three distinct categories: public (such as drones used by DOD and CBP), civil (drones used for commercial purposes), and "model airplanes."[252] However, in a sweeping statement, the FAA effectively banned all previously unregulated drone operation: " The current FAA policy for UAS operations is that no person may operate a UAS in the National Airspace System without specific authority. For UAS operating as public aircraft the authority is the [Certificate or Waiver of Authorization], for UAS operating as civil aircraft the authority is special airworthiness certificates, and for model aircraft the authority is AC 91-57."[253] This notice of policy has been attacked as overly broad.[254] The policy essentially banned the use of UASs for commercial purposes, and in so doing, "the FAA fell victim to the kind of conflation of technologies and uses that so often drives technopanics. Technologically, the FAA did not differentiate between military UASs weighing thousands of pounds and radio-controlled children's toys weighing mere ounces."[255] Limitations directed in the NPRM that UAVs must weigh less than 55 lbs., remain within the VLOS of the operator, fly at a maximum altitude of 500 feet and maximum airspeed of 100 mph, be flown only in daylight hours, and not operate over any person not directly involved in the operation.[256]

In 2011, Congress passed the Sovereignty and Use of Airspace Act, asserting that the "United States Government has exclusive sovereignty of airspace of the United States" and a "citizen of the United States has a public right of transit through the navigable airspace."[257] It further determined "the Administrator of the Federal Aviation Administration shall develop plans and policy for the use of the navigable airspace and assign by regulation or order the use of the airspace necessary to ensure the safety of aircraft and the efficient use of airspace."[258] The following year, Congress passed FAA Modernization and Reform Act of 2012. That Act "tasked the FAA to promulgate rules, implement regulations, and provide general guidance to incorporate the three categories of drones,[259] including those for commercial use,[260] into the National Airspace System"[261] and to "develop a comprehensive plan to safely accelerate the integration of civil unmanned aircraft systems."[262] It defined a UAS as "an aircraft that is operated without the possibility of direct human intervention from within or on the aircraft. The term 'unmanned aircraft system' means an unmanned aircraft and associated elements (including communication links and the components that control the unmanned aircraft) that are required for the pilot in command to operate safely and efficiently in the national airspace system."[263] The definition was so broad that it could include radio-controlled model aircraft (RCMA), "a type of flying device not traditionally regulated by the FAA."[264] The broadness was likely intentional, "given that the FAA policy says that UASs can be 'controlled either manually or through an autopilot using a data link,' that their dimensions can range from 'wingspans of six inches to 246 feet,' and that they can 'weigh from approximately four ounces to over 25,600 pounds.'"[265]

Further recommendations for inclusion of UAS language into 14 CFR § 91.113 for dealing with UAVs were made in 2013 by the UAS Aviation Rulemaking Committee (ARC). Among the ARC's recommendations were language requiring operators to "detect and avoid" and "sense and avoid" other aircraft.: "Detect and avoid is the capability to see, sense or detect other aircraft and take the appropriate action to remain well clear from and to avoid collisions with other aircraft….means more than collision avoidance…Sense and Avoid (SAA) …is the capability of a UA to remain well clear from and avoid collisions with other airborne traffic. SAA is the combination of UAS Self-Separation plus Collision Avoidance as a means of

compliance with 14CFR Part 91, §91.111 and §91.113."[266] As many states felt these guidelines were insufficient, 96 domestic drone bills were considered by 43 states to regulate the use of drones in state airspace, with eight states enacting drone laws.[267] Even the very definition of a drone varied from state to state, with Illinois, Oregon, and Montana providing "sparse definitions that leave significant room for interpretation, while Florida, Idaho, and Tennessee include more detailed definitions with several identifying elements."[268]

In 2015, the FAA crafted its first rules for recreational users, and by that winter, more than 450,000 hobbyists registered in the government's user database. The new rules also affected commercial users.[269] "Previously, companies had to apply for special permission from the F.A.A. to operate drones. The government has issued more than 6,000 approvals and about 7,000 companies are on a waiting list for approval. When the new rules go into effect in 60 days, companies will no longer have to gain that special exemption."[270] The FAA has also begun to implement regulations "that allow for routine UAS operations of gradually increasing risk and complexity…. including the June 2016 Small UAS rulemaking ([14 C.F.R. Part 107] commonly called Part 107), which established conditions under which small UAS operators are allowed to routinely fly for largely commercial purposes."[271] While Part 107 exempts recreation drones from registration, the regulations place significant restrictions on civil drones. For example, while drones may now transport cargo, they are limited to a combined aircraft and payload weight of 55 lbs. and are prohibited from conducting interstate commerce.[272] When 14 CFR Part 107 went into effect on August 29, 2016, the "results were underwhelming. Drones remain recreational craft and tools for expensive photography. Commercial drone operations are novelties. The prohibitions swallow the allowances. Drones may not operate in populated areas, cargo operations are all but prohibited, and drones are virtually tethered to their operators. Drones are thus relegated to the fringes of the national airspace."[273]

The FAA Reauthorization Act of 2018[274] provided a means for the FAA to grant waivers to the operations not normally permitted on a case-by-case basis. "The Flight Standards Service has issued waivers for some UAS operators–including commercial and government users–to operate beyond-visual-line-of-sight or at night for purposes including inspection of hurricane damage and aerial photography."[275] However, of the nearly 14,000 requests for waivers were received as of December 2018, only 2,000 were approved.[276] In February 2019, the FAA issued a proposed rule "to expand the operations permitted under the Part 107 rulemaking to allow operations over people and at night in certain conditions."[277] In its internal Fiscal Year 2019 Implementation Plan, the FAA identified a variety of new types of operations that could be enabled in the next few years, including: beyond visual-line-of-sight operations (BVLOS, primarily below 400 feet); small-cargo delivery operations; urban air-mobility passenger operations; large cargo and inspection operations (the FAA has approved—on a case-by-case basis—limited experimental operation of large UAS to conduct inspections).[278] The "FAA has also identified a need for research and development, including for systems that would enable UAS to detect and avoid other aircraft and hazards. To help address these needs, FAA has established programs to draw on private industry's resources and state and local governments, including the provision of air navigation services. Longer term, however, the extent of activities needed to carry out FAA's statutory role in the operation, oversight, and enforcement of established rules and systems related to UAS is still unclear."[279] A Low Altitude Authorization and Notification Capability (LAANC) has been implemented, and a UAS traffic management system is under development,[280] with the FAA selection in

April 2020 of test site participants for Phase 2 of the unmanned aircraft Traffic Management Pilot Program.[281]

While the new rules permit a range of businesses to use drones under 55 pounds, there are still a number of restrictions (such as pilot age, distance from airports and height at which the drone can be flown), and they "stopped short of giving a green light to package delivery, a goal of Amazon and Google, which have pushed regulators to create rules that would allow them to transfer part of their ground-based delivery systems to the sky. The new guidelines mandate that a commercial drone operator must always have the machine within line of sight — a rule that, for now, makes delivering packages unfeasible. Still, the action brings the drone delivery vision one step closer to reality. And experts predict that in time federal regulators will get comfortable with the notion."[282] "With this new rule, we are taking a careful and deliberate approach that balances the need to deploy this new technology with the FAA's mission to protect public safety," said Michael Huerta, the FAA administrator. "But this is just our first step. We're already working on additional rules that will expand the range of operations."[283]

The Strategic and Economic Logic of UAS Trade

Historic alliances and partnerships created due to common security interests, cultures and core values have transitioned to forms that require greater levels of economic interdependence as national prosperity is competing with domestic security as a driving interest in future relationships. "For much of the twentieth century, leaders and policymaker…viewed the strategic importance of trade, and of international economic policy…largely through the lens of military strength…the role of a strong economy was to act as an enabler, supporting a strong military, which they saw as the best way to project power and influence…leaders have come to see the economic clout that trade produces as more than merely a purse for military prowess: they now understand prosperity to be a principal means by which countries measure and exercise power."[284]

Increasing border disputes in the Taiwan Strait, South China Sea and East China Sea in the Asia-Pacific, and the Baltics, Black Sea, and eastern Mediterranean Sea in Europe is driving global demand for long endurance UAS. As the market leader in developing long endurance UAS technologies, the U.S. can address the UAS needs of developing nations while simultaneously addressing the complement of U.S. economic and foreign policy interests. First, the global economic potential of strategic UAS is estimated to be $22B by 2026.[285] This figure is conservative as it does not account for dual use technologies applicable to the commercial market. However, the importance of this opportunity is the increase in U.S. economic productivity that could result. Furthermore, the trade opportunity can create secondary opportunities for manufacturing or logistical support in partnership countries that would strengthen the interdependent relationship and facilitate continuous transactions.[286] Current U.S. UAS Trade and Export policy has been very limiting, forcing U.S. industry to support U.S. domestic and military needs. Although policies are being evaluated to facilitate transfers to allies and partners, the process continues to be slow. This presents an opportunity to not just our economic competitors, but to countries like Iran and China, they are able to offer capabilities to expand their economic and foreign policies objectives. Second, by sharing the UAS capabilities, the U.S. can expand its Intelligence, Surveillance, and Reconnaissance (ISR) network by incorporating the real-time and persistent collections of regional partners while transferring cost of collection activity to the trade partners. Essentially, we are offsetting

ISR related costs, gaining relevant intelligence but sharing economic and technological advantage. Additionally, by cross leveling collection activities with regional partners for wide-area ISR surveillance missions, this would free up other U.S. ISR platforms to perform missions for which they are uniquely suited.[287] Third, by expanding interdependencies on economic and security interests, the U.S. can advance other broader mutual interests such as the rule of law, human rights law, and democracy.

UAS Trade Policy

The DOS, Department of Commerce (DOC), and DOD are the primary approvers and evaluators of foreign transfer requests but regardless of whether the UAS transfers occur under the authority of the United States Munitions List (USML) or the Commerce Control List (CCL) the key objectives and transfer conditions are the same. Guiding these lists are two federal regulations, the ITAR for military application and the Export Administration Regulation (EAR) for dual-use civilian and military capabilities. The guiding principles of these documents are in protecting sensitive technological information and managing the potential use of force. Additionally, a host of other statutory, regulatory and policy guidance influence the execution of any UAS transfers.[288]

Recognizing the technological advantage, growing global demand, and the leading role that the U.S. should play in the global UAS market as the largest developer, procurer and user, the DOS updated in 2015, UAS Export Policy guidelines. Additionally, on May 21, 2019, President Trump approved a new policy on the export of UAS to update and replace the 2015 UAS export policy. The new policy does not deviate much from the bureaucratic requirements of the first policy, but it did clarify and simplify the objectives and transfer conditions.

If the intent were to communicate that the U.S. was willing to share or trade innovative capabilities but first needed to gain consensus for responsible export and subsequent use standards. The results did not match assumed intent. The U.S. has provided strategic UAS capabilities for surveillance purposes prior to 2015 but only to specific allies and partners. With demand levels significantly higher, the U.S. did not optimize its' opportunities economically, militarily, or diplomatically to advance U.S. interests. Additionally, the topic was more controversial in relationship to the transfer of armed drones. The U.S. took an approach to deter use of UAS for offensive capabilities even though surveillance platforms could be easily converted from surveillance to armed. The consequence of U.S. transfer denials led to the "Pentagon is scrambling as China 'sells the hell out of' armed drones to U.S. allies."[289] And to further demonstrate their willingness to abide by U.S. conditions to access capabilities, allies and partners from forty-eight countries endorsed the U.S. led effort for international rules for armed drones trade[290] only to experience the limitations of, "The new export policy puts in place stringent conditions on the sale or transfer of military UAS."[291] Although the enhanced controls on the export and principles for proper use standards were meant to ensure the UAS systems were used lawfully and responsibly and "in accordance with international law, including international humanitarian law and international human rights law,"[292] the bureaucracy of request reviews and approval, end user agreements, end user monitoring, and mandatory training requirements, delayed capability transfer to allies. The implications of the new policy to "enhancing the operational capabilities and capacity of trusted partner nations, increasing U.S. interoperability with these partners for coalition operations…and easing the stress on U.S. force structure for these capabilities"[293] were slow to materialize.

Economically, the expected opportunity for U.S. industry to pursue dual use capabilities in the growing $10 billion plus commercial UAS market[294] were inhibited by stipulations in the UAS export policy as it maintained its commitment to the MTCR. The MTCR "subjects transfer of military and commercial systems that cross the threshold of MTCR Category I (i.e., UAS that are capable of a range of at least 300 kilometers and are capable of carrying a payload of at least 500 kilograms) to a 'strong presumption of denial' for export."[295] Essentially, policy influencers and decision makers believed that autonomous drones, even surveillance ones, could be used as lethal projectiles. This may discount the fact that manned aviation platforms have played such roles through history, specifically, Japanese kamikaze warfare in WWII and the attack on the World Trade towers.

Summary

Many Americans dislike regulations, particularly of industry, however, the UAS industry requires adequate regulation to encourage development while guaranteeing safety. Growth in the UAS industry is poised to explode, particularly if regulatory and technical issues can be resolved so that UAVs can begin routine flights in national airspace.[296] The FAA "needs to provide regulations in terms of levels of safety, rather than simple prohibitions, for at least the pilot and line-of-sight requirements and the prohibition on flight over humans."[297] Several things could assist this in happening.

The FAA "should enact more stringent registration requirements for all drone operators" and "must require drone registrants to tag all drones with long-range radio frequency identification devices or some other similar mechanism. Third, a smartphone app should be developed to provide all citizens with a quick and convenient means to identify drones via Radio Frequency."[298] With these steps, the UAS industry could grow into a healthy future that will benefit not just consumers but the general public by encouraging the kind of research and development that will take public uses, including for C4ISR, to the next level.

Mobilization and Supply Chain

Introduction

UAS as defined previously, consists of various components creating an ecosystem comprised of manufacturers, operators, software and service providers, and data analytics purveyors.[299] Each component of the system has a unique supply chain and mobilization challenges. These challenges compound based on UAV type and sector in which they operate. The impacts of the degradation of the DIB, continued budget uncertainty, and years of globalization pose several risks to the defense UAS supply chain and its ability to mobilize in the event of a national emergency. The DOD, its industry partners, along with Congress all must work in tandem to mitigate these risks and to secure America's competitive advantage in the UAS and larger C4ISR industry.

Though MALE/HALE UAVs make up three-fourths of the defense UAV market in the U.S., the tactical, low-altitude, and civil UAV markets continue to grow at a faster rate than the defense UAV market and is expected to realize technology advancements.[300] Based on the expected growth of the small UAV (sUAV) market and possible mobilization capacity available in both the defense and civil sectors, this section will include information beyond just the MALE/HALE market.

In 2017, President Trump issued Executive Order 13806, directing the Secretary of Defense to assess the current state of the DIB. The assessment identified risks in the Aerospace sector supply chain that apply to the UAS ecosystem. The assessment team identified the following forces driving risk in the DIB and more specifically the UAS market: Uncertainty of Government Spending, the Decline of U.S. Manufacturing, Capacity Constrained Supply Market, Foreign dependency, and production limitation and security.[301]

UAV Supply Chains

Due to regulation, the UAV supply chains need to be reviewed separately, from the defense market and commercial market perspective. For defense MALE/HALE platforms, the DOD relies on the large defense firms such as Northrup Grumman and Boeing. Since most defense firms that produce aircraft for the DOD also supply UAVs and associated software solutions, they often co-locate manufacturing locations of MALE/HALE UAVs with their aircraft production facilities. While domestic firms complete manufacturing of UAVs, firms "typically source components from third-party suppliers that specialize in relevant aircraft parts."[302] Therefore, Defense firms may not receive all information required to adequately ensure the security of supply chains from these suppliers, most of which are overseas.

While tactical, low altitude UAVs only account for 6.3% of the defense UAV market,[303] this market continues to grow as the DOD explores micro-UAV use, and technology continues to evolve. Defense firms also manufacture many of these UAV platforms, but the smaller platform size opens the market to more suppliers and expands to the international market. The civil UAV market consists of hobbyists and commercial UAVs and is not subject to the same import/export restrictions as the defense market. Similar to the defense sUAV market, this market is open to international suppliers and is unique in that many UAVs in this market are low-cost imports. Supply chains for these UAVs are typically unknown as they are manufactured, imported, and sold as complete systems on the commercial market.

UAV Supply Chain Limitations

The MTCR impacts the DOD's MALE/HALE UAV market by imposing restrictions on the export of specific UAVs, their associated subsystems, and production facilities. The current limits not only impede U.S. exports of UAS but also the U.S.'s ability to import UAVs from our Allied partners. Though not governed by the MTCR like the MALE/HALE UAVs, many tactical UAV platforms or components are still subject to ITAR. Because of this, these platforms are also generally manufactured by domestic firms with supply chains that include third-party suppliers like the larger platforms. For this reason, the defense UAV market has remained largely a domestic market.[304] The sUAV and commercial sector procure only the smallest UAVs from international suppliers.

A similar supply chain concern that encompasses all categories of UAVs is the risk associated with shortages of electronic components. As noted earlier, nearly all UAV manufacturers rely on some parts from third-party suppliers. The lead time for electronic components could increase because of tariffs imposed that slow importation or because of demand from other industries such as the cell phone or automotive industry.[305] To further exacerbate the issue, the source of these electronic components can often be hard to track. Many come from Taiwan, but some come from China, adding another security concern. A finding from DOD's DIB assessment found "several vulnerabilities in the electronics supply chain, including counterfeits, a lack of traceability, and insufficient quality controls throughout supply tiers."[306]

Finally, fiscal uncertainty has adverse impacts on the supply chain for UAVs. Fiscal uncertainty comes from volatility in the funding priorities from the DOD based on funding approvals from Congress or multiple continuing resolutions that ultimately keep programs from starting. The former concern can cause rapid decreases in funding, directly impacting suppliers in the industrial base. The latter fear would deter new entrants from participating in the defense market if they did not have an existing relationship with the DOD before the continuing resolution and cancellation of a program.[307] Additionally, typically only large defense firms can absorb the additional cost of waiting for approved funding. If small businesses intend to compete in the defense market, they risk going bankrupt or acquisition by a large defense firm. Acquisitions and mergers collapse the number of suppliers and can potentially create a sole source supplier, which creates a point of failure within the industry.[308]

UAV Supply Chain Risk Mitigation

Recognizing the impact on America's ability to maintain a military advantage in the UAS market, President Trump revised the current UAS export policies by allowing for more accessible sale of UAVs to our Allied partners.[309] Increased export capacity makes the U.S. a viable supplier instead of China, which only loosely participates in the MTCR.[310] In response to the sUAV concerns, the DOD announced their intent to expand the small UAS industrial base because of supply chain concerns. The Chinese firm DJI has dominated the sUAV market, and DOD's Ellen Lord, USD A&S, stated concerns that we "became dependent on them both from the defense point of view and the commercial point of view."[311] By driving demand domestically for sUAVs manufactured in the U.S., Lord hopes that manufacturers in the U.S. will respond accordingly. Developing a domestic industrial base for sUAVs will also increase the mobilization capacity without reliance on foreign firms. The use of additive manufacturing can also mitigate some of the supply chain risks, bring critical production back,

and help the U.S. deglobalize. Additionally, identifying UAV components capable of production using additive manufacturing will allow the DOD to continue to focus on those components that create a more significant security risk. To mitigate the fiscal uncertainty within the industry, the DOD team suggests "expand[ing] direct investment in the lower tier of the industrial base…to address critical bottlenecks, support fragile suppliers, and mitigate single points-of-failure."[312] This incentive would encourage the lower-tier suppliers to remain in the industry while deterring the acquisition/mergers of the defense firms.

Security of Supply Arrangement (SOSA)

An additional effort to expand the DOD supply chains is through established formal, bilateral agreements with international partners within which the two countries agree to support each other with defense products and services. These arrangements encourage the shared use of materials, logistics processes and furthers systems interoperability. Through SOSA, the DOD can request priority delivery from companies in partnering countries. The prioritization of DOD contracts, subcontracts, and orders from international companies can help control supply chain management of defense equipment. The program administered through Deputy Assistant Secretary of Defense for Industrial Policy, currently, has SOSA's with Australia, Canada, Finland, Italy, The Netherlands, Norway, Spain, Sweden and United Kingdom.[313] If future conflicts occur the U.S. would likely be fighting along with some of these partners and the added strength of having UAS interoperability and a more robust supply chain would benefit the warfighting capability.

SOSA Expansion

Throughout the C4ISR Industry Study it is apparent that technical innovation is conducted globally, with many of our international partners facing similar national security and fiscal challenges. Through the use of SOSAs the U.S. can "strengthen alliances and attract new partners"[314] to improve resiliency and integrity of critical national security supply chains. Establishing mutually beneficial relationships supports the strategy and increases strength against adversary influences. This coupled strength acts as a force multiplier, enabling access to the technological, innovative, and production capabilities of global partners. Expanding SOSAs with other countries, to establish alliances with Indo-Pacific, NATO, France, Germany, Japan, Taiwan, and bring resiliency to the U.S. supply chain.

Human Capital

In the defense UAS market, human capital includes skilled labor for development and manufacturing, as well as UAV operators, while the sUAV market only includes skilled labor. The development and manufacturing portion of the UAS industry relies on cutting-edge software and innovative solutions to complex problems. This portion of the industry is enticing for start-up technology firms looking to break into the market because the technology is continuously evolving, and the large defense firms can capitalize on the expertise of these start-ups by using them as subcontractors or, in some cases, acquiring them. As noted previously, the UAS market, mainly the sUAV market, is growing exponentially. The speed of growth creates increased demand for software engineers in a sector already "experiencing a shortage of workers with critical hardware and software design capabilities."[315] This shortage transfers into the civil sector of sUAVs, where the same demand for software engineers exists.

With the intent to expand the sUAV industrial base, the defense sector will begin to compete directly with the commercial sector for talent.

MALE/HALE UAVs and a portion of tactical UAVs within the defense sector require operators. All need maintenance support, and some require launch/recovery personnel. Except for maintenance support, the Services typically fill these requirements with military personnel. In some cases, when demand requires, the DOD relies on government-owned, contractor-operated (GOCO) operations, for example, when the Services placed UAVs into service without the associated support personnel.[316] For MALE/HALE UAVs, the regulatory requirements for pilots limit the supply of personnel available to conduct operations. In some instances, long training times for qualification render UAVs on-hand, but unavailable until operators complete training.[317] A critical component of the DOD's Unmanned Systems Integrated Roadmap is the creation of modularity between the services with a focus on shifting functionality from hardware to software.[318] This shift in functionality creates an even shorter lead time to get personnel trained to standard. Currently, the acquisition and procurement process has not fully caught up with the speed of technology, so the DOD is always a step behind when implementing technology. However, if the procurement process rights itself, then the DOD needs to find new solutions to solve the human capital problem.

Human Capital Supply Chain Mitigation

The rapidly changing pace of technology will continue to put a strain on the recruiting and retention of software engineers to support the DOD. The U.S. needs to continue to expand the domestic industrial base to decrease foreign dependence for sUAVs. Additionally, the demand could incentivize small start-up technology firms to bring their innovation and ideas to the DOD, rather than to international companies that may have less regulatory requirements. The DOD must continue to partner with industry to adopt, where feasible, their best practices for transitioning to a more modular capability with plug and play architectures that allow for more agile upgrades of technology.[319] To mitigate the training risk and reliance on military personnel, the DOD needs to consider revising the mix of uniformed military personnel, federal civilians, and contractors who operate and provide support for MALE/HALE UAVs. Analysis reveals the DOD can gain substantial cost savings by replacing some military personnel with federal civilians. The DOD has indicated they are willing to use contractors since they have agreed to GOCO contracts previously. By splitting the requirements down into smaller pieces, much like breaking the UAS down into smaller pieces, the DOD can analyze which portions are inherently governmental and require a uniformed or civilian employee. To limit the long lead times for training, the Services must work directly with their acquisition professionals regarding the timelines for fielding and backward plan the training requirements for military personnel to achieve combat readiness when fielded. Where this may not be feasible, the DOD could then research the possibility of allowing contractors to supplement the uniformed personnel until enough could get trained.

Hiring additional workers to conduct a major expansion is two-fold. If expanded production also requires software development, hiring workers with the appropriate labor skills could prove problematic given the already existing shortage. Additionally, the manufacturing labor market has continued to decline with increased globalization, so hiring workers to increase production could also be a problem. Finally, depending on the type of UAS, the DOD may need to increase the number of pilots/operators to meet production capacity or risk having

platforms on hand with no trained or licensed operators. If the situation allows, hiring contractors can mitigate requirements to impose long training requirements on the Services.

Mobilization

After years of globalization, "U.S. Companies lost their domestic supplier ecosystems."[320] Rather than building products, companies outsourced the manufacturing process causing U.S. dependency on these manufacturers for critical components of some of our sensitive equipment. The electronics example identified earlier illustrates this dependency and is also an example of a constrained supply market where competing commercial market demands impact defense capacity. Despite the supply concerns, defense firms can increase production levels when necessary. Last August, Northrup Grumman announced an increase in its production capacity of the Global Hawk from an average yearly output of 3-5 to 12. To accomplish increased production, Northrup Grumman remodeled one of their current production facilities. Additionally, Northrup Grumman remodeled much of their California facility to increase production and capacity.[321] Similarly, during a visit with General Atomics, leadership noted the company could double their current output by adding shifts without hiring new employees or adding new facilities. Though not directly related to the UAS market, Lockheed Martin, another large defense firm, recently announced over $450 million in accelerated payments to affected suppliers in the DIB.[322] Support efforts like this from our defense partners, give the U.S. confidence in the ability of its defense firms to increase production and capacity.

Based on the examples above, in the event of a national emergency, the UAS industry has several other industry sectors in the U.S. and her Allied partners to leverage for support if necessary. Since the UAS industry already resides within the Aerospace Industry, the first logical source of support for MALE/HALE UAVs, beyond the current defense firms, is from commercial airline manufacturers. Using the existing aircraft manufacturing infrastructure partially mitigates requirements for the acquisition of additional tooling or facilities. Additionally, using existing infrastructure at airports and private hangars already designed to support aircraft increases capacity and minimizes requirements for other infrastructure. If the response requires support for sUAVs, the commercial UAV market is most prepared to provide additional production capacity without a significant degree of difficulty. It may not require the acquisition of tooling. Concerning the software requirements of the industry, any technology start-ups and offerings to firms supported by venture capitalists offer opportunities for support in an emergency.

An additional option is the Defense Production Act (DPA) of 1950, which grants the President several authorities, useful for mobilizing the DIB for national defense and emergency preparedness. The objective of this act is to expedite action, when necessary, in response to national defense issues. The DPA authorities serve as tools that can be applied to support mobilization across the UAS ecosystem. Title III, Expansion of Productive Capacity and Supply allows the President to incentivize the industrial base to expand the production and supply of critical materials. It accomplishes this through multiple alternatives or incentives such as loans, loan guarantees, direct purchase, and purchase commitments. The Title III Program is administered by the Industrial Policy office and could be used to mobilize companies which have technical skills, processes, capabilities to produce defense materials, but may not necessarily be involved in defense production. Title III actions are initiated with a Presidential Determination to authorize its use. In June 2019, President Trump issued the

Presidential Memorandum to enact these authorities to strengthen the industrial base for sUAS in response to the American Drone Security Act of 2019. The act bans DOD's use of DJI UAVs. The memorandum triggered the program office to engage American commercial companies as sources of sUAS to determine mobilization options and assess industry skill, experience, and capacity to become domestic suppliers.[323]

Summary

The DOD should continue its efforts to expand the domestic sUAV market and increase additive manufacturing for UAV components to reduce foreign dependency. Service personnel sections should partner with the acquisition community to ensure synchronized delivery of platforms and operators, and the defense market should enhance its partnership with the commercial UAS sector to share best practices and capitalize on dual-use capabilities.

Despite some concerns within the UAS industry supply chain, the MALE/HALE UAV sector can increase production capacity in the event of a national emergency. The U.S. government and the DOD continue to address current concerns to increase exports and the domestic industrial base. As the DOD continues to increase participation in the sUAV market, its expanded partnership with industry will ensure the best posturing to meet all regulatory guidelines administered by the FAA. The expanding UAS market creates an enormous opportunity for the U.S. and serves as a launching pad into future development in the autonomous and artificial intelligence markets. The Department must continue to support innovation in this market to retain its advantage.

Industrial Security

Introduction

For the UAS industry, the USG, Industry, and Academia would all agree that they participate in a larger national innovation base; each working to secure their assets in a volatile environment to ensure organizational success. Dr. Jude Sunderbruch, Executive Director of the Air Force Office of Special Investigations (AFOSI), noted in his recent lecture to the Eisenhower School that the USG approach to industrial security is trying to protect: (1) the ability to create intellectual property (IP) (e.g., basic science & innovation) that is critical to national security (e.g., AI) (2) the ability to produce defense and national security goods (e.g., UAS Platforms), and (3) the ability to apply these goods in a context that will enhance their national security BLOS technology.[324] For the USG this remains focused only on defense related UAS technologies. The commercial U.S. UAS industry is focused on bringing new innovative technologies to production; capital investment being critical to surviving in a highly competitive environment. U.S. academia is focused on talent recruitment to include researchers, engineers, and students; allowing programs to establish strong reputations through cutting edge innovation. Each effort remains speculative unless it addresses specific threats.

The Threat

Industrial security has only recently received the attention it deserves due to an acknowledgement by senior leaders that China and Russia have enjoyed phenomenal success in stealing our nation's most innovative technologies and closing the technology gap and with it the U.S.' competitive advantage.[325] Our adversaries, China in particular, utilize non-traditional collection strategies to acquire the U.S'. innovative technologies to include:

> *"Scientist, engineer, student, and academic exchanges, co-development and coproduction agreements, commercial proposals and associated business visitors, trade fairs, exhibits, and air shows, sales to third-party nations, multinational corporation transfers, international programs (such as fusion, space, and high energy), international meetings and symposia on advanced technology, patents, clandestine or illegal acquisition of military or dual-use technology or equipment, dissemination of technical reports and technical data, whether published, oral, or via oral/ visual release, dissemination of technical reports under DoDD Manual 5400.07, DoD Freedom of Information Act (FOIA) Program, dummy corporations, and by acquiring an interest in U.S. industry, business, and other organizations."*[326]

This list is extensive and offers U.S. adversaries opportunities to camouflage their activities within normal business operations–the initiatives businesses and academia use to innovate, market, and sell their products.

Specific to the global UAS market, 2,088 of the total UAS companies are headquartered in Five Eye (FVEY) countries (Australia, Canada, New Zealand, United Kingdom, and the U.S.). Of these, 81 FVEY companies are at risk for known/suspected Chinese or Russian influence. Of these 81, 11 have direct Chinese or Russian financial investment, 66 have manufacturing in either China or Russia, and 25 have subsidiaries in China or Russia.[327] Before actions can be taken, the USG and its Industry and Academic partners must first acknowledge the risks and costs associated with addressing vulnerabilities–finding a balance in those very same partnerships.

Assessing Risk and Finding Balance

Dr. Sunderbruch opined that to determine risk you must first understand the threats and vulnerabilities less the protection and mitigation strategies. His formula is as follows: threats multiplied by vulnerability minus protections and mitigations equal risk. To be successful, risk is always a balance.[328] As Sun Tzu noted, we need to see all the threats and risks whether they are theft of critical technology (USG), higher production costs or theft of IP (Industry), or lost reputation due to foreign talent recruitment (Academia). The parties need to agree because all three need to be incentivized to work together, finding balanced solutions to the threats and risks.

To find balance all parties must understand the costs and benefits from each other's perspective. There are questions of individual liberty (who one work with, talk to, share information with) and what is best for society. How we protect our information may impact our ability to share that information and could impact our ability to innovate. With vetting comes costs and impacts on trust. If the nation institutes in depth vetting, what are the costs and how will our allies/partners react to questions on trust? Security is never efficient and if we increase security, how will this impact the speed at which we develop and bring products to market. Will increased development costs, in a highly competitive and resource constrained industry like the UAS industry, increase mergers and acquisitions, push companies out of the market, or encourage sales to parties with capital to spend (China)? The USG, industry, and academia have worked independently on these problems (with some exceptions) and developed their own solutions based on their priorities. What may not be as clear is that these issues are linked to all parties and need a 'enterprise' solution.

Government Efforts

Congress gives the President the authority to control the export of certain items for national security, foreign policy, and other economic reasons.[329] The Departments of State, Commerce, and Energy license these items and the Department of Defense conducts the due diligence for security reviews. Furthermore, Congress retains the authority to prescribe sanctions on specific countries. Together, the President, Congress, and subordinate agencies work to control the export of various items, including UAS technology, to ensure the U.S. maintains a competitive advantage against its adversaries. The USG is not illuminating the threat to our nation's supply chains in partnership with industry and academia, relying instead on the intelligence community to identify threats overseas.

The Department of State

The DOS is one of the nation's greatest economic assets because it seeks to market U.S. products and services, including UAS technology, around the world. The DOS plays a critical role in industrial security through its authorities with respect to controlling imports and exports of defense related items. The DOS uses authorities laid out in the Arms Export Control Act (AECA), Executive Order (EO) 13526, and the National Security Decision Memorandum (NSDM) 119 to mitigate risks for transferring critical technology to allies/partners overseas. Though not focused on the commercial UAS industry, Congress addressed threats to U.S. military UAS platforms in Section 848 of the FY2020 National Defense Authorization Act by restricting the use of micro-electronic components manufactured in China.[330] An illumination

capability would enable the DOS to identify and mitigate threats in conjunction with their current authorities.

The Commerce Department

Where the DOS focuses on defense related articles, the Export Administration Act (EAA) gives the DOC the jurisdiction over items of export/import that do not fall under the authority of other agencies; the State Department's USML being one. The Commerce Control List (CCL) is a list of controlled technologies that require additional scrutiny and security reviews before approving licenses. The CCL published on 23 May, 2019 notes that commercial UAS platforms with ranges over 300 km are controlled items.[331] Those falling outside this narrow range of systems are not controlled and their sale is not reviewed for its impact on national security or its impact to U.S. innovation and competitive advantage in the UAS market. The under 55lb systems make up 57% of the global systems market; covering a majority of the under 300km range and a significant part of the innovation within the global ecosystem–a significant issue if not addressed by USG, industry and academia.

The Department of Defense

The DOD has several subordinate elements tasked with aspects of industrial security including the Undersecretary of Defense (USD) for Research and Engineering (R&E), the USD for Acquisition and Sustainment (A&S), the USD for Intelligence and Security (I&S), the USD for Policy (P), and the DOD's Chief Information Officer (CIO). The Department's focus remains securing the DIB but its impact can be felt across the National Security Innovation Base as industries like UAS have both a commercial side and military/government side and companies operating in both adopt the higher security requirements required of USG.[332] The USD-R&E "stablishes policy, guidance, education, and training for Science and Technology (S&T) and program protection to include anti-tamper (AT), hardware and software assurance, supply chain risk management (SCRM), system assurance, and engineering secure cyber resilient systems and advises senior leaders"[333] on protecting programs and critical technologies like UAS. The USD-A&S "considers industrial security when developing and implementing international acquisition, exportability, and armaments agreements to ensure appropriate risk mitigation actions are taken with regard to acquisition systems."[334] This relationship includes industry, DOS, and the Commerce Department. The USD-I&S overseas defense intelligence resources, conducts assessments (see J2/DIA below for details), and resources security requirements.[335] The USD-P provides technical analysis and transfer/export control input to DOS and Commerce Departments.[336] Lastly, the USD-CIO "oversees DOD's Voluntary Defense Industrial Base Cybersecurity Program threat information sharing activities,"[337] particularly those involving industry, academia and allies/partners. Many of the policies, regulations, plans and intelligence could be shared with the greater U.S. commercial UAS industry to enhance security.

The Joint Staff and the Defense Intelligence Agency

The Joint Staff J2, Intelligence Directorate, provides finished intelligence to meeting operational impact assessments with regards to technology, goods and services, and technology transfer as requested by the Secretary of Defense (SECDEF) and senior government leaders. To accomplish its mission the J2 leverages the collection and analysis capabilities of the Defense Intelligence Agency (DIA) as well as those of the National Ground

Intelligence Center (NGIC). DIA is responsible to conduct these assessments, represent the DOD within the large government enterprise, performs end user checks on technology transfers, assesses the impact of these transfers on U.S. security, and assists in identifying critical technologies – increasing security across the defense industrial base.[338] Despite these capabilities and benefits to the USG, DIA is unable to analyze U.S. companies and institutions (ex. Universities) or any joint venture between a U.S. and foreign partner.[339] The USG can leverage DIA's intelligence and analysis resources to inform industry and academia on the foreign threat (talent recruitment, front companies, espionage etc.) to enable development of security policy, rules, and processes specific to commercial/academic organizations.

DOD Support to the Academic Community

Section 1286 of the FY 2019 NDAA directed the SECDEF to establish an initiative to protect those products stemming from academic research. More specifically, Congress ordered the SECDEF to work with academia to: (1) protect intellectual property (IP), sensitive information, specialized human capital (researchers), and information concerning technologies tied to our national security, (2) limit foreign influence, including foreign talent recruitment programs, by countries attempting to steal U.S. technology related to DOD research, science and technology, and (3) support the development of U.S. talent in critical scientific and engineering disciplines. The objective of this initiative is to develop the situation, make recommendations to Congress for legislative or administrative action, identify gaps in legal authorities, and identify best practices that can be established under new guidelines. Limitations on this initiative include the DOD's requirement for individual consent to collect identifying information and lack of legal authority to conduct security screenings to identify foreign influence.[340] Gathering data and analyzing possible foreign influence is one-way academia could incentivize the USG to partner towards a balanced industrial security plan. This Congressional directive was in direct response to adversarial actions, specifically China, which have shown capabilities in exploiting DOD-funded academic research to enable their own military and economic progress.[341]

The Academic Community

Academia, specifically U.S. research universities and colleges, are focused on a different set of priorities from government and see threats and risks differently. These institutions are focused on recruiting the best professors, researchers, scientists, and students to capture as much of the government and corporate investment (grant dollars) as possible. This drives innovation and builds a strong reputation which enhances recruiting. To convince these institutions of the seriousness of the threat, they will need to be incentivized to change their way of thinking about threats and risks.

In its report to Congress on 13 September 2019, the U.S. DOD's Research Protection Initiative noted that U.S. academic institutions were at risk from several factors to include:

> *"The inappropriate dissemination of pre-publication ideas, data, or technologies …by unethical peer-reviewers …(and/or) by unethical actors with access to USG-funded research activities, …the loss of scientific talent through foreign recruitment programs, the recruitment of USG-funded researchers into foreign talent programs, …the influence of USG research funding through the exploitation of the scientific funding process."*[342]

These risk correlate directly with the threats posed by foreign states, especially China. The report notes our universities and colleges are at risk for loss of scientific talent which will result in an unfair advantage for foreign universities and a loss of reputation which will lead to challenges in recruiting the world class talent required for our own research institutions.[343] If U.S. research institutions are unable to attract the best talent, both in students and scientists, it will eventually lead to a drop in UAS innovation and loss of U.S. competitive advantage in this critical field. The report to Congress security highlights incentives USG could use to partner with academia to enhance security across the UAS industry.

Industry

Like academia, industry has its own set of priorities and sees threats and risk differently from government. Industry's focus has and always will be on cost, schedule, and performance which affect profits and a company's finance strength. CEOs are becoming more aware of the risks of foreign influence and are willing to address security with the loss of IP and their competitive advantage within the industry – a direct threat to their bottom line. Industry has access to their supply chains and could provide this data to its partners in USG and academia, but this will come at additional administrative costs and potentially expose proprietary data. Additionally, Industry needs the resources of USG (DOS) to compete globally and legal protections to ensure fair competition. The USG needs to provide supply chain data to illuminate to identify threats and the most efficient way to address this is in partnership with industry.

Summary

The gap across government, industry and academia appears to be a lack of data to illuminate what technologies are critical, where they are being developed (academia/labs), where they are being manufactured (industry), and what interest our adversaries have in those critical components and functions. To understand this vast ecosystem, we must illuminate the networks by industry, then by company and institution, triage the risks, mitigate those risks, and then formulate a means by which the greater enterprise can overwatch for changes, new vulnerabilities, and losses of those technologies–in short, SCRM. The Air Force's Office of Commercial and Economic Analysis (OCEA) is leading the way developing SCRM capabilities within the DOD and is mentoring a fledgling effort within the Navy (OCEAN – Navy).[344] SCRM is a unique capability requiring industry knowledge, specialized skills (finance, data analytics, cyber security training etc.) and vast amounts of data not organic to USG. There are several commercial firms (e.g., Deloitte or Ernst & Young) providing SCRM capabilities; several of which are already working with the DOD and Industry to illuminate, triage, mitigate, and monitor threats to their customers. The questions that remain are how the partners leverage SCRM analysis and apply it within their own organizations.

Recommendations and Conclusion

The Industry Study recognizes the U.S. still holds a formidable position against peer/near-peer competitors like China and Russia in the C4ISR realm. However, without the U.S. taking critical actions, adversaries will close the gap. While the U.S. currently spends two and a half times more than China on defense and still holds a demonstrated technology advantage, the DOD must invest, innovate, and reform policy to keep the edge in C4ISR and UAS. The DOD should implement the following six recommendations to better align funds and policy to achieve the objectives of the NSS and NDS and keep the edge against GPC.

Investment

Recommendation #1 – Integrate third offset technology to bolster UAS operability in a degraded environment

Investing in the development of third off-set strategy technology is the bedrock upon which the future C4ISR ecosystem must be built. In a rapidly changing environment, intelligence, surveillance, and reconnaissance data must be shared while operations are planned across dispersed locations. As the DOD seeks to counter revisionists threats and emerging near peer competitors, the continued evolution of the UAS, specifically MALE and HALE systems, through third offset strategy technology is essential to ensure the DOD remains postured to operate in an A2/AD environment in direct support of the C4ISR mission.

Recommendation #2 – Invest in supply chain risk management, the U.S. industrial base, and international partnerships to increase capacity and resiliency of supply chains for UAS.

UAS component supply chains are vulnerable for several reasons since MALE/HALE UAVs are mostly domestically manufactured, the individual components are less likely to be made in the U.S. and defense contractors often do not have visibility into the tier 3 supply chain of these components. This lack of visibility raises the risk for foreign influence to include theft of intellectual property, critical components, and functions. The U.S. needs partner with industry to address supply chain risk management while investing in the DIB and international partnerships to mitigate supply chain vulnerabilities. The USG should leverage the DPA to incentivize domestic production and development of the sUAV sector to encourage innovation, increase capacity, and decrease foreign dependence. The degradation of the Defense Industrial Base puts the supply chain at risk. Globalization, mergers, and acquisitions within the DIB has added to the degradation of production capabilities. Moreover, an uncertain budget landscape and barriers to entry deter small businesses from risking participation in the DIB further exacerbating supply chains.

To mitigate supply chain vulnerabilities, the U.S. needs to invest in the DIB and international partnerships. President Trump has already leveraged the DPA to encourage domestic development of the sUAS market. By continuing to use Title III of the DPA, the U.S. can incentivize domestic productions and development of the sUAV sector to encourage innovation, increase capacity and decrease foreign dependence. Another way to increase domestic production is to leverage additive manufacturing. Identifying UAV components capable of production using additive manufacturing will allow the DOD to address those components that create a more significant security risk. Lastly, expanding Security of Supply agreements with international partners to provide priority delivery of components from foreign companies.

Recommendation #3 – Develop a STEM talent management program to train, recruit and retain talent needed for technical fields including UAS and C4ISR

Universities are projected to produce 30% of graduates needed to fill critical computer specialist jobs, and 80% of those graduates are foreign nationals with limited opportunities to stay and work in the U.S..[345] This was exacerbated when President Trump reduced H-1B Visas (denial rates increased from 4 to 18% between 2016 & 2019), resulting in a further reduction of available STEM professionals.[346] To overcome these challenges, the U.S. should develop a STEM Talent Management program to train, recruit, and retain talent in these fields. STEM jobs need to be held in the same regard as professions such as doctors or lawyers to appeal to America's youth. To accomplish this the program should incentivize schools to include STEM curriculum in K-12 programs and institute an out-reach or marketing initiative to entice prospects. Lastly, the program needs to steer STEM talent to fill government jobs by creating onramps through vocational, high school and college programs to prestigious opportunities like NASA, Federal Bureau of Investigation (FBI), industry, DOD etc.[347]

Policy Reform

Recommendation #4 – Reduce UAV Classification to enable trade, innovation, and market responsiveness

The U.S. is the global leader in MALE/HALE markets, but export controls based on MTCR and ITAR require DOS approval. This makes it hard to compete with countries like China and Israel who are selling UAVs to this burgeoning market. President Trump loosened restrictions with the 2018 UAS Export Policy update, but MTCR sales are still limited. Remove pre-transfer limitations contained in MTCR Class 1 (UAS flying further than 300km and carrying more than 500kg) and execute existing post sale periodic review to ensure compliance to terms of transfer. Additionally, include zero-day faults to remotely disable capabilities if systems are being misused. Reduce pre-transfer reviews and leverage greater end user monitoring to risk mitigate potential transfer violations and speed capability transfer.

Recommendation #5 –Replace line of sight FAA requirement with existing technologies to realize flight safety, spur innovations and enable U.S. competition

The second aspect of the UAS market is domestic regulation. Competition in the UAV market is imperative to spur innovation and sustain America's competitive advantage in UAS and the larger C4ISR. Yet, domestic policy and regulations related to UAVs are stifling that innovation and forcing commercial business abroad. To grow the domestic UAS market, create domestic manufacturing and encourage innovation, the FAA needs to create regulations with a balance between safety and innovation and help drive public acceptance of commercial drone use. The FAA is responsible for efficient and safe use of U.S. airspace; however, its restrictive commercial UAV regulations prohibit technology advancements. As we learned during a virtual FAA field visit, the FAA is easing regulations (slowly) and has a waiver process. Yet only about 1% of requests have been approved; more must be done. As Wynn notes, applications of UAS "aren't limited by technology or imagination; they're only limited by regulations. We need a streamlined regulatory environment that allows for the safe deployment of unmanned systems into our nation's transportation infrastructure so we can begin to reap the full benefits of this technology." Removing the LOS requirement for commercial UAVs while ensuring there are requirements in place for flight safety (cameras, collision avoidance systems, sensors, unmanned flight management, etc.) will open up UAV applications such as

logistics, inspections, delivery of emergency supplies, humanitarian assistance) and allow spin-on/spin-off technologies.

Innovation

Recommendation #6 – Develop an innovation strategy focused on long-term national security and prosperity objective, establish innovation integrator, and properly resource transformational R&D

The third objective in the NDS is to reform the department for greater performance and affordability. Innovation, technology development, and a focus on research and development can set a path to achieve this objective. However, the DOD and, more specifically, the NSIB piecemeals direction and guidance from several national strategic documents such as the NSS, NDS, NDAA, and specific topic strategies such as the Unmanned Systems Integration Roadmap or the Executive Order on the American AI initiative. These similarly purposed but disparately written documents lead the U.S. to lack focus and prioritization for innovation efforts across the Triple Helix. For instance, DARPA/IARPA and MIT Lincoln Lab's initiatives are informed by national security objectives, but their efforts and priorities are determined internally. As a result, the DOD and the larger whole-of-government will create inefficient duplication of effort, stifle collaboration, waste precious resources, and most likely not attain National Security objectives. The U.S. should author an innovation strategy with focused objectives and establish an innovation integrator to communicate and implement the strategy to ensure proper whole-of-government prioritization of innovation initiatives and resources. The integrator role would facilitate formal collaboration to realize synergies and reduce duplicative efforts, as well as close gaps, and harness efforts to efficiently realize technological superiority.

An additional impediment to the U.S. retaining the competitive edge and achieve NDS objectives is the decreased prioritization of R&D funding. During early cold war years, the U.S. significantly led the world in R&D, comprising 69% of reported investments. However, between 1967 and 2017 that statistic flipped with the U.S. accounting for only 25% of global R&D investments. Within that 25%, federal R&D spending has also decreased significantly. Commercial R&D spending bridged the gap somewhat but has been focused on applied research. DOD needs to correct this problem and adequately resource R&D efforts. With the impending defense budget cuts and impacts of COVID-19, this will be a significant challenge. Analyzing manned programs and continuing with the DOD "night court" budget drills are ways to identify funds for R&D program use. Prioritizing a focus on innovation and R&D funding will help the DOD and the U.S. maintain their competitive edge and meet the GPC challenge.

Conclusion

The C4ISR Industry Study was charged with identifying challenges within the industry for the next 5-15 year with specific focus on maintaining the technological edge and operating in a contested environment. While the group initially focused specifically on MALE/HALE UAS, as a DOD staple for warfighting, a quick determination was made that the sUAV sector would be a critical aspect to meet the challenges of the future. Additionally, the long-term DOD investment strategy does not optimally meet future warfare environments and changes must be made to better align resources against adversarial threats and warfighting capabilities. Overall, the industry currently holds a technical edge but strict foreign and domestic

regulations, supply chain weaknesses, STEM skill shortage, and lack of focused R&D prioritization in emerging UAS technologies provide roadblocks and vulnerabilities that will hinder the C4ISR industry to achieve mission imperatives. The six recommendations outlined above will put the DOD on the right path today, through investment, innovation, and policy reform, to meet the GPC challenges and the contested environments of the future.

Appendix A: Firm Briefs

Northrop Grumman

Link to brief on SharePoint: Northrop Grumman Firm Brief

Lockheed Martin

Link to brief on SharePoint: Lockheed Martin Firm Brief

Thales

Link to brief on SharePoint: Thales Firm Brief

Safran

Link to brief on SharePoint: Safran Firm Brief

End Notes

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[346] Koehler.
[347] Ortiona.; Manyika and Raven.