U.S. AIR FORCE

Small Unmanned Aircraft Systems (SUAS) Flight Plan: 2016-2036

Bridging the Gap Between Tactical and Strategic

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Small Unmanned Aircraft Systems (SUAS) Flight Plan: 2016-2036

Bridging the Gap Between Tactical and Strategic

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EXECUTIVE SUMMARY

The Air Force has reached an inflection point. 25 years of continuous combat operations coupled with budget instability and lower-than-planned top lines have made the Air Force the smallest, oldest, and least ready force in its history. Yet, our nation faces an ever growing and evolving list of challenges ranging from near-peer nation-state expansionism to the rise and prominence of regional violent extremist organizations with global ambitions. Concurrently, the global technology proliferation enables capabilities once reserved for select few Nation-states. Additionally, the Air Force must continue to support a majority stake in the shared global commitment to address emerging humanitarian crises around the globe at a moment's notice. While each of these challenges drive an increase in the demand for responsive and persistent airpower, the Air Force faces an operating environment where unpredictable and eroding budgets have shrunk force structure capacity as well as the defense industrial base upon which it heavily relies. In an effort to meet these challenges, the past two decades have seen the rise of Remotely Piloted Aircraft (RPA) providing a unique and cost effective projection of airpower effects. However, an insatiable demand continues to drive requirements that greatly outpace capacity and budgets. To reverse these trends within the context of fiscal reality, now is the time to capitalize on mature RPA advancements born over a decade of war and leverage the technological explosion of commercial Small Unmanned Aircraft Systems (SUAS) that is upon us. This intersection of unmanned technology maturation with widespread industry innovation will enable the rapid advancement of equivalent RPA capabilities in a compact, cost benefiting, and operationally successful family of SUAS focused on traditional Air Force roles and missions.

SUAS hold promise for the future. Commercial markets are accelerating SUAS research, and production is quickly outpacing archaic military acquisition processes. Military and academic research labs continue to develop technologies and concepts with application across low and high threat environments. Sensors and platforms, along with their associated ownership costs, continue to shrink enabling employment at half the size of traditional RPAs. SUAS are also overcoming the tyranny of distance with both beyond-line-of-sight (BLOS) and long-endurance capabilities which, through low cost solutions, enables increased density over an objective to complicate an adversary's engagement solution. This in turn, forces adversarial resource expenditures inverse to our own, effectively bending the relative cost curve to our advantage. The key fact is that historically tactical SUASs are now mature enough to augment or assume Air Force requirements with operational and strategic impact. Despite these developments, the Air Force finds itself behind the power curve having forgone the opportunity to embrace and operationalize these developments through a dedicated acquisition program, let alone an independent line of funding. We have reached the point where SUAS applications are greatly outpacing strategy and policy. With this nascent capability lying dormant, the Air Force must take significant steps to integrate and institutionalize an Airmen-centric family of SUAS systems as exponential force multipliers across the Air and Cyber domains. This Flight Plan outlines an aggressive but realistic vision on how to do just that.

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1. Introduction

The asymmetric benefits of Unmanned Aircraft Systems (UAS) have dramatically increased the effectiveness of Air Force operations and afforded the service an additional persistent strike capability. However, that advantage is fleeting. As technology proliferates, UAS are becoming commonplace among allies and adversaries alike. Fiscal constraints make it difficult for the Air Force to recapitalize a multitude of its major weapons systems and mission sets given the current costs. The Air Force must look for innovative approaches to sustain the nation's unparalleled military advantage and meet operational needs. Technical innovations in Small UAS (SUAS) enable that pursuit.

The SUAS Flight Plan articulates a vision and strategy for continued development, operation, and sustainment of SUAS to increase joint force capability from the tactical to the strategic level. In recent combat operations, SUAS have proven their practicality and tactical flexibility. Technological advances have enabled payload miniaturization, increased persistence, and expanded Beyond Line of Sight (BLOS) communications. These technological innovations coupled with expanded concepts of operation (CONOPS) point to new uses for SUAS in anti-access and area denial (A2AD) environments in addition to counter-UAS applications.

More capable SUAS have the potential to meet the Secretary of the Air Force's 'Bending the Cost-Curve' initiatives. While fiscal realities limit the development of exquisite solutions for all but the most critical missions, integrating SUAS with existing assets will increase offensive capabilities at a relatively low cost. These innovations also pose a direct threat to our adversaries' defensive capabilities. The Air Force must aggressively pursue innovative SUAS strategies to provide asymmetric advantages in these challenging environments. The SUAS Flight Plan strives to combine innovation with operational concepts to maximize Air Force ISR core competencies.

1.1. Vision

The United States Air Force will deliver affordable and integrated SUAS with the following attributes:

- **Exponential Force Multiplier:** Cross-domain integration across mission sets to augment and/or fill requirement shortfalls.
- **Easily Integrated Asset:** Deployable by a variety of means, providing flexibility, reach, penetration, and integration with joint force missions.
- **Cost Savings Enabler:** Affordability in development, procurement and employment providing cost-effective capabilities with larger aircraft quantities.
- **Partnership Builder:** Facilitates teaming between the joint force, interagency, coalition partners, academia, and industry to drive innovation and efficient use of research and development (R&D) investments.

1.2. Scope

The SUAS Flight Plan follows a similar strategy set forth in the 2013 Department of Defense (DoD) Unmanned Systems Integrated Roadmap[1] and the USAF 2013 Remotely Piloted Aircraft

1 Department of Defense. "Unmanned Systems Integrated Roadmap: FY2013-2038." Reference Number: 14-S-0553. http://www.defense.gov/Portals/1/Documents/pubs/DOD-USRM-2013.pdf

(RPA) Vector[2]. It serves as a forward thinking, vision document that is advisory in nature. As technology enables new capabilities to be integrated, the concepts within this document will be periodically updated in accordance with the Strategic Master Plan.

1.3. Current Environment

With increasing operational demand for full-motion video (FMV) and other intelligence, surveillance, and reconnaissance (ISR) support, the Services and their acquisition programs have been significantly challenged to meet Combatant Commander needs. As budgets continue to decrease, the SUAS capability-affordability advantage will become more relevant. Continued miniaturization, long-endurance power plants, and command and control (C2) technologies will increase payload options, persistence, and utility across the range of military operations.

1.3.1. Unmanned Aircraft Systems

The USAF entered the modern era of unmanned systems in 1995 when the 11th Reconnaissance Squadron began flying the RQ-1 Predator. Since then, the appetite for unmanned systems increased dramatically. In addition to the MQ-1, the Air Force currently employs the MQ-9 Reaper, RQ-4 Global Hawk, and RQ-170 Sentinel at locations around the world. The Air Force acquired its first SUAS, the Desert Hawk, in 2002 through the Force Protection Airborne Surveillance System (FPASS) Program to support Operation Iraqi Freedom. As the Desert Hawk was phased out, a more capable inventory of SUAS was acquired by Air Force Special Operations Command (AFSOC) to enhance ISR capabilities.

The current Air Force SUAS inventory includes: RQ-11B Raven, RQ-20A Puma AE, Wasp III, and RQ-12A Wasp AE. These systems are primarily utilized by Special Tactics Teams and Security Forces. Thus far, the USAF has employed these systems for limited, tactical objectives; however, SUAS have demonstrated their potential to execute a much broader range of full-spectrum missions in the future.

1.3.2. Family of Systems (FoS)

The Chairman of the Joint Chiefs of Staff Instruction (CJCSI) 3255.01[3], Joint Unmanned Aircraft Systems Minimum Training Standards (JUMTS), organizes UAS into 5 groups based on altitude, weight and speed (Table 1). As a general rule, altitude is the primary consideration due to airspace access requirements and required training, while weight and speed are secondary parameters. Training standards require consideration of the size and application of the UAS. The Air Force classifies anything the size of the MQ-1B Predator or larger as an RPA, while everything smaller than 1,320 pounds is a SUAS. The current Air Force SUAS inventory is represented by Group 1 systems. The MQ-1B and MQ-9 / RQ-4 are represented as Group 4/5 systems, respectively.

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2 "United States Air Force RPA Vector: Vision and Enabling Concepts 2013-2038." 17 February 2014.

3 CJCSI 3255.01. "Joint Unmanned Aircraft Systems Minimum Training Standards (JUMTS) with Change 1." 4 September 2012. http://www.dtic.mil/cjcs_directives/cdata/unlimit/3255_01.pdf

	Group	Max Weight (lbs)	Normal Op Alt (ft AGL)	Speed (kts)	Representative Aircraft
SUAS	1	0 - 20	<1,200	< 100	Puma AE (RQ-20A), Wasp AE (RQ-12A), Raven (RQ-11B), Shrike™ *
SUAS	2	21 - 55	<3,500	< 250	Aerosonde*, Scan Eagle*, Silver Fox*
SUAS	3	< 1,320	< FL 180	< 250	Blackjack (RQ-21A)**, Tigershark*

* Not a Program of Record in the USAF. Utilized for T&E or Services Contract. ** Participated in the CDD but not the CPD.

Table 1: Representative USAF SUAS Platforms by Group

CJCSI 3255.01 groupings translate into basic UAS qualification (BUQ) levels requiring Federal Aviation Administration (FAA) mandated training requirements to integrate with manned air vehicles in the National Airspace System (NAS). Similarly, a North Atlantic Treaty Organization (NATO) Standard Agreement (STANAG)[4] has been developed to integrate UAS employment by NATO members. However, other coalition partners may use different classification standards and training requirements. Some of these requirements may be unique and will require additional training for operator qualifications in those countries.

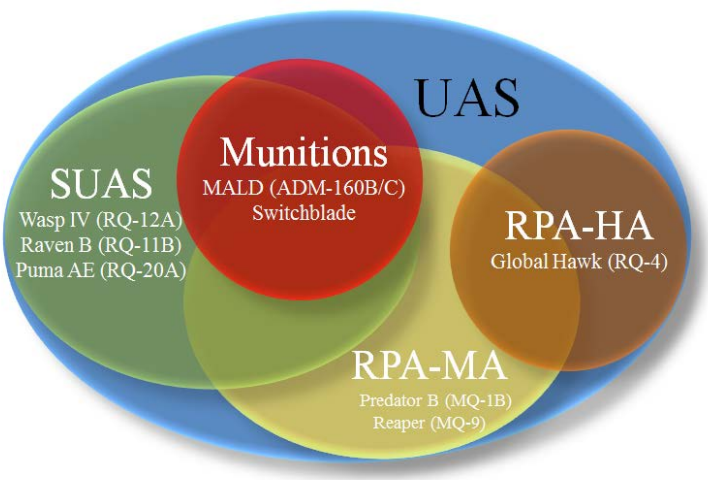

Figure 1: Capability Overlap between UAS and Munitions

The distinction between SUAS and guided munitions becomes obscured with technological advances and operations concept development (see Figure 1). For example, a platform such as the Miniature Air Launched Decoy (MALD, ADM-160B/C) is classified as a guided munition, not a SUAS. In general, the decision to classify expendable SUAS as a munition has merit because their acquisition and training strategies closely align. However, there are limitations to a guided munition classification for systems that are operated more like a SUAS. For example, the precision and expertise needed to conduct strike and coordination operations requires increased training and standards development not typically seen with guided munitions. As

4 ATP 3.3.7. "Allied Training Publication: Guidance for the Training of Unmanned Aircraft Systems (UAS) Operators." Edition B, Version 1. April 2014.

future operational concepts, technologies, and autonomy evolve, the current methodology of classifying these systems must also evolve with them.

Future SUAS capabilities will continue to blur the lines of distinction. As shown in Figure 2, even the term "SUAS" is defined differently by each of the respective Services. As UAS proliferate and take on more traditional mission sets, it is essential for the DoD to understand SUAS complexities and appropriately update the current UAS classification system. The Air Force should lead this effort by adopting the FAA definition and advocating for alignment across the DoD to facilitate a common grouping lexicon that is relevant for this evolving area.

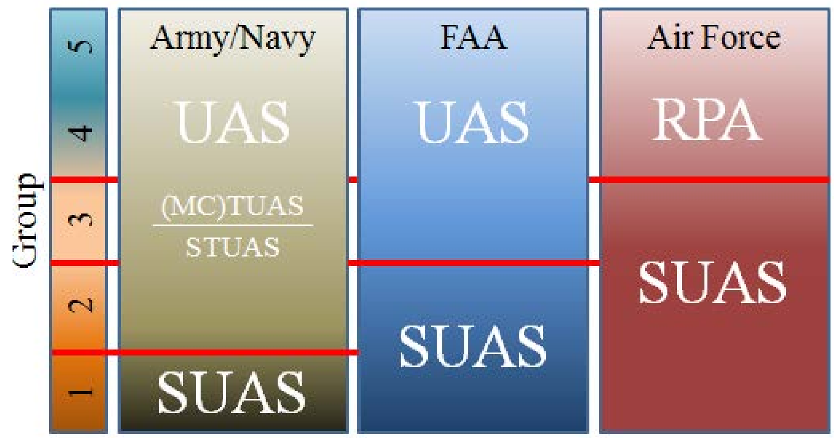

Figure 2: Different Definitions of "SUAS"

1.3.3. Systems Description and Terminology

Much like their larger RPA counterparts, SUAS are procured as a system comprised of several components (see Figure 3): an air or ground control segment (ACS/GCS), one or more unmanned aircraft, launch and recovery element (LRE), and various mission payloads either integrated into the existing system or operated by separate equipment. Issues arise and compound when single-source solutions are procured to meet urgent needs. Though these systems may meet a valid capability gap, they often remain limited functional solutions unable to integrate into the larger network or be operated by common equipment. While these single-source solutions offer rapid capability to the warfighter, their lack of interoperability results in additive sustainment costs and/or the need to completely replace systems when any one major component changes, is upgraded, or a new capability emerges.

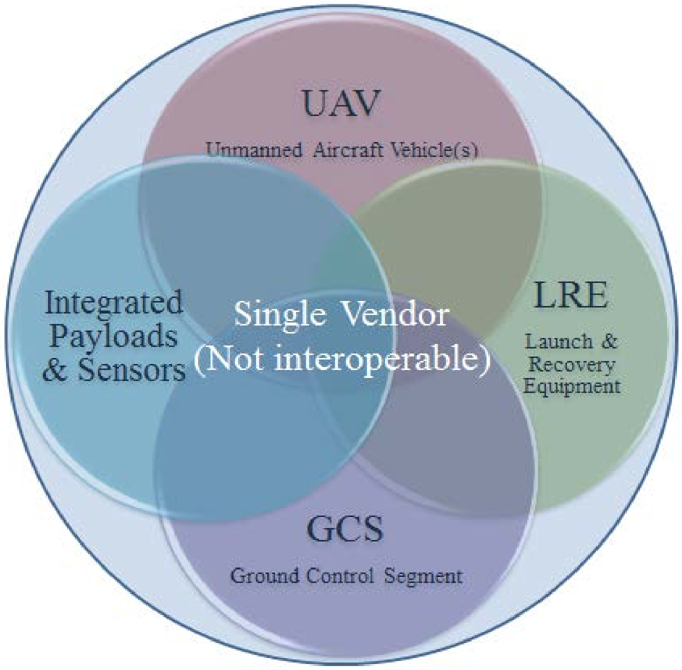

Figure 3: SUAS Components

1.3.4. SUAS Operations

SUAS have proven their worth on the battlefield providing real-time actionable information to tactical ground units. Their organic placement provides the commander and individual service member life-saving situational awareness (SA) and represents a significant technological advancement in air and ground warfare. SA provided by full FMV and Geospatial Intelligence (GEOINT) dominates current urgent operational needs from the battlefield.

Current SUAS provide a "hip-pocket" reconnaissance, surveillance, and targeting acquisition (RSTA) capability to ground units to reduce the fog of war. SUAS are employed by conventional and special operations, Security Forces, COMCAM, and the Air Force Office of Special Investigations (AFOSI) to provide point, route, and environmental reconnaissance, target acquisition and development, battle-damage assessment, as well as other innovative applications. Additionally, the miniaturization of signals intelligence (SIGINT) payloads has created an exponential growth in intelligence collection capabilities further increasing the applications of SUAS within combat environments.

Though they are limited by size, weight, and power, most Group 1 platforms are hand-launched and have similar capabilities of some larger platforms. As such, SUAS serve as organic RSTA for Special Operations Weather Teams (SOWT), Special Operations Command (SOC), and COMCAM. Utilization of smaller organic systems reduces the strain on RPA and manned ISR aircraft or provides support that is otherwise unavailable.

Further development and integration of these systems within the larger ISR collection and processing, exploitation, and dissemination (PED) enterprise will dramatically increase their utility but also could overburden PED resources. New technologies and concepts of operations will be necessary to accommodate the increase in data. Auto-PED, enhanced sensor overlays, and real-time mosaic would alleviate much of the manpower intensive activities. From an operational perspective, the Air Force could provide unit PED of the SUAS with discoverability by the larger ISR/PED enterprise. SUAS are flexible enough to be adapted for other mission sets including counter-UAS, security of vast or strategic military complexes, and as innovative enhancements to current capabilities in anti-access, area denial environments requiring conscious decisions about the collection management.

1.3.5. Core Function Lead (CFL)

The SUAS community faces many of the same challenges as RPA systems, most notably, a fiscally constrained environment. USAF SUAS primarily were procured with Overseas Contingency Operations (OCO) funds, therefore, they are not "normalized" (no Programs of Record, Program Office, etc.) like other Major Weapons Systems. Therefore, the first step needs to be an examination on how SUAS can address enterprise capability gaps. Per AFPD 10-9 dated 8 March 2007, AFSOC is the Lead Command for Air Force SUAS Groups 1-3[5], and they function as the CFL for Groups 1–3 SUAS capability development and integration. In this role, AFSOC developed a vision that includes a requirement for a FoS approach in their SUAS Initial Capabilities Document (ICD)[6]. Within this FoS strategy, the Air Force teamed with the Marine Corps and the Navy to develop a Small Tactical Unmanned Aircraft System (STUAS) ICD[7] and Capabilities Development Document (CDD)[8]. STUAS will provide a potential Group 3 capability to support a wide variety of missions across the operational spectrum. AFSOC's operational needs consist of:

- BLOS tactical ISR and targeting
- Kinetic low-collateral damage engagement of time-sensitive targets
- Rapid reaction expeditionary persistent ISR
- Near-real-time networked collaborative information
- Standoff, adverse-weather-capable, multiple-target-track/kill from AFSOC aircraft

As the Air Force institutionalizes SUAS, efforts to find affordable, innovative solutions to operate within A2AD environments, civil UAS operations, and counter adversary UAS, and support key facility security operations may require some realignment of CFL duties to other MAJCOMs with equity in those mission areas.

Current AFSOC SUAS operations (Figure 4) provide a good starting point for development of a more expansive USAF long-range acquisition plan for Groups 1–3 FoS. This strategy will enable an Air Force SUAS capability that integrates seamlessly into a variety of roles and mission areas across the full spectrum of conflict. More importantly, this SUAS Flight Plan will inform

5 Air Force Policy Directive 10-9. "Lead Command Designation and Responsibilities for Weapon Systems." 8 March 2007.

6 AFROCM 02-04-02; AFROCM 03-05-04.

7 JFROCM 021-07.

8 AFROCM 08-08-03; JROCM 219-08; "United States Air Force RPA Vector: Vision and Enabling Concepts 2013-2038." 17 February 2014. 25-6

the Air Force of art-of-the-possible capabilities that SUAS contribute to core missions, such as Global Integrated ISR and Global Strike.

1.3.6. Synchronization of Effort

Each Air Force Major Command (MAJCOM) has its own resources, requirements, and acquisition activities to organize, train, and equip assigned air forces for joint operations. In some cases, planning for these functions has been consolidated into lead MAJCOMs. However, this can lead to a disjointed and confusing process to ensure shared UAS systems are both interoperable and integrated. The Air Force should establish a dedicated planning function to facilitate cross-Service communications in order to leverage expertise for capability development and payload synchronization in different regions and environments until such time as a validated requirement necessitates the need to assign a Program Executive Office (PEO) and stand up a System Program Office (SPO) for this effort with possible Joint Program Office (JPO) participation. This synchronization of effort must focus on commonality of platforms, payloads, architecture, control elements, and training to ensure limited resources are efficiently applied to gain the largest operational benefit. This will provide MAJCOMs and other operational organizations a central point of contact within the AF to standardize and reduce duplication of effort in this area of SUAS that was a significant problem within other Services.

Currently, AFSOC is the only Air Force acquisition activity dedicated to SUAS; however, they primarily focus on functional capabilities at the Group 1 size. Future requirements from other MAJCOMs are expected to encompass Groups 2-3 as well as more conventional mission applications. A SUAS SPO would be ideally suited to managing these disparate mission requirements while working to ensure interoperability and operational efficiencies across all UAS. Additionally, the SPO would serve as the arbitrator in a growing SUAS inventory, ensuring proper life cycle management and sustainment activities occur.

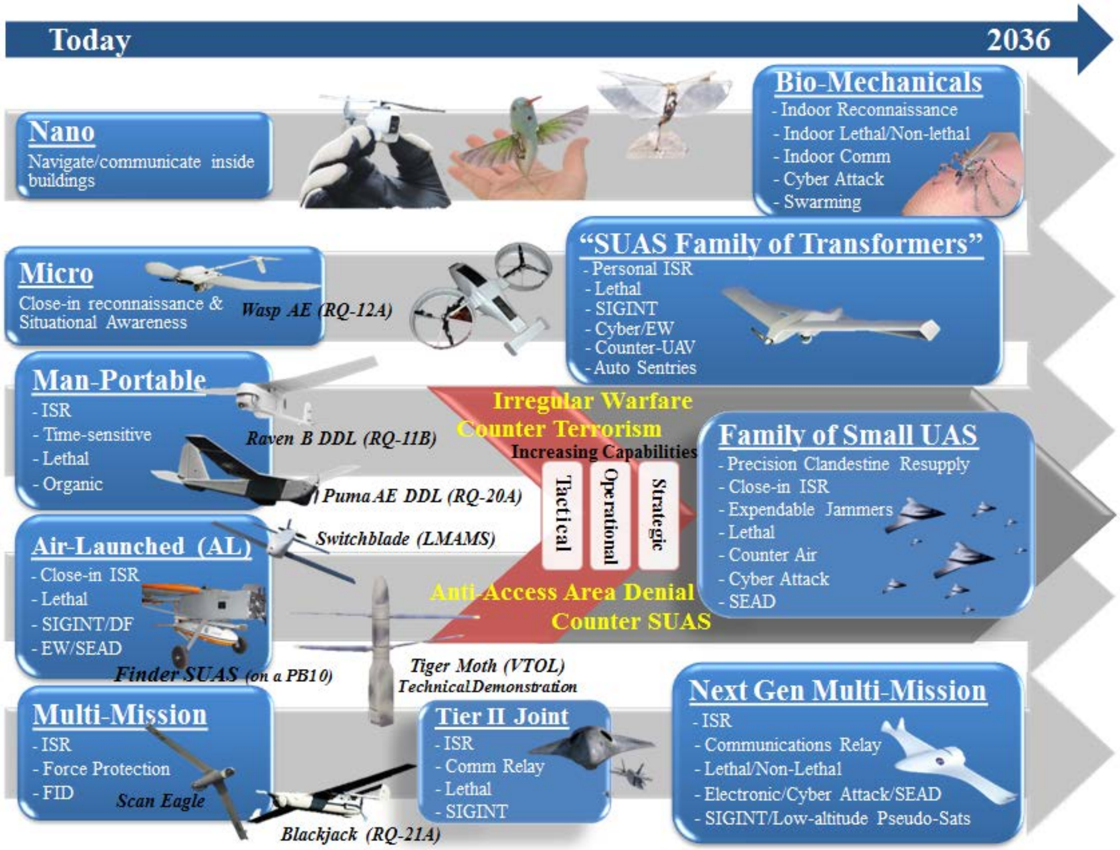

Figure 4: AFSOC SUAS Family of Systems Vision

1.4. Future Environment

The operational environment will continue to evolve rapidly requiring innovative technology development that enhances and expands operational employment concepts. Expected civil commercial expansion of SUAS will incite broad, rapid technological advancement of certain capabilities with military utility. A common open system architecture would allow synergy between Services and enable harnessing uneven technological advancement across sensors, platforms, and power systems. These advances will enable SUAS to help counter emerging threats across the tactical to strategic spectrum of operations by way of their unique capabilities. Future use may include employment as an airborne improvised explosive device (IED) to defeat enemy airborne threats. As capabilities improve and experience with SUAS increases, new SUAS roles and missions will emerge to provide critical augmentation to RPA and manned ISR capabilities. SUAS provide great value to Air Force competencies due to their life cycle cost savings thereby expanding capabilities such as attritability and/or expendability that we do not have today. Large numbers of lethal or network attack SUAS may be employed to saturate enemy communications networks or highlight enemy defensive forces. A SUAS swarm will complicate adversary response while freeing up more exquisite assets to conduct missions consistent with their technology and priority. By employing SUAS (rather than large, expensive systems) to address low-end missions, we will bend the cost curve and ultimately maintain U.S. advantage across the full spectrum of conflict.

1.4.1. Operational Vignette

On the future battlefield, U.S. forces engaged in a multi-domain operational environment require flexible and adaptable options at the forward line of troops to combat our adversaries and carry out our nation's policies.

As soldiers advance from a sea base to land, Air Force aircraft loiter overhead at 60,000 ft. On cue, these high-altitude long endurance (HALE) aircraft each deploy large numbers of SUAS from internal launchers. This swarm of attritable small aircraft saturates the airspace with pre-programmed actions to locate and carry out electronic and kinetic attacks against the enemy's Integrated Air Defense System (IADS). Once a suitable portion of the IADS is defeated, a second wave attack of high-value, low observable airborne platforms commences enabled by the on-scene electronic and kinetic attack SUAS.

As more SUAS swarms are delivered, a secure low probability of detection (LPD)/low probability of intercept (LPI) network is enabled to link all SUAS with participating manned and unmanned systems. With a robust and assured network in place, "mother ships" deploy numerous SUAS configured for missions including signals intelligence, full motion video, electronic warfare, airborne early warning radar, and suppression of enemy air defenses (SEAD). With these SUAS in place, analysts begin receiving near real-time data from the newly formed network of SUAS. This data provides immediate targeting information to stealthy manned and unmanned assets and strike-configured SUAS for kinetic attack of enemy positions and infrastructure. As aircraft continue to arrive on scene, they seamlessly join the network and re-task existing SUAS to accomplish their assigned missions. Mission requirements and risk will determine whether SUAS are expendable or recoverable. Additionally, low-dollar MALD systems will draw costly enemy surface-to-air missile (SAM) activity, which further underscores our cost curve advantage. Through the use of networked synergistic capabilities, SUAS will enhance ground, air, and sea warfare of the future in a cost-effective manner. Although much of the technology necessary to carry out such a mission is in development, significant challenges remain that require careful investment.

1.4.2. Objectives

The current fiscal environment elicits many challenges that military planners must overcome due to shrinking budgets and rapid adversary advancements. In order to thrive in this future environment, the Air Force must find ways to counter enemy technological advances with cost-effective solutions. SUAS offer affordable solutions to mass assets against enemy forces while preserving manned and high value systems for use against high priority targets. The pace of SUAS technological advancement is such that policy, guidance, and decisions made today may not be applicable to the force 20 years from now. The Air Force must begin planning now for future SUAS capability enhancements to avoid being outpaced by our adversaries.

1.5. Trends and Characteristics

The 2013 DoD Unmanned Systems Integrated Roadmap pointed out seven environmental trends and characteristics and their effect on unmanned systems. These seven trends remain valid and continue to impact all unmanned systems, including SUAS.

- **Pressure for reductions in federal budgets.** Budget reductions increase demand for more affordable systems with the same or similar capabilities as current aging and legacy systems. In several mission areas, integrating SUAS into Air Force core competencies will offer savings over legacy systems thereby aiding force modernization in the midst of a shrinking defense budget.

- **Operational issues will be more complex.** Many legacy systems still in use are a challenge to modernize with new technologies that are made to function in complex environments of the future. However, SUAS offer the potential to design-in cost effective modular concepts or "Plug and Play" (PnP) systems that enable rapid adaptation to a wider range of operating environments.

- **U.S. military forces will be rebalanced.** The 2014 Quadrennial Defense Review (QDR) calls for the need to rebalance: for a broad spectrum of conflict; to sustain our presence and posture abroad; and to ensure capability, capacity, and readiness within the Joint Force[9]. SUAS provide inherent capabilities to warfighters across the globe to carry out their missions despite challenges such as anti-access and area denial.

- **Violent extremism.** The last decade demonstrated that violent extremism is a long-term challenge the U.S. will continue to combat both at home and abroad. While al Qaida's core has been degraded, other similar or even more devastating extremist groups have expanded their reach into new areas while encouraging homegrown terrorism. To track, monitor, and counter terrorist groups on a global scale, we must field systems that are acquired cheaply, in sufficient numbers, with increasingly autonomous roles.

- **Unmanned technologies will continue to improve.** While the U.S. defense industry is expecting reductions in spending and development, global UAS and SUAS markets anticipate annual growth at 3%[10] and 21.7%[11], respectively. UAS and SUAS affordability appeals to many nations with small defense budgets thereby expanding innovation in areas once deemed too costly to pursue.

- **Cyber domain will be a contested environment.** Small nation states as well as independent actors and extremist groups have used cyber-attacks to gain an advantage against superior adversaries. Just as UAS and SUAS have been integral to land, sea, air, and space domains, they will also play a key role in the cyber domain.

- **Enemy unmanned systems.** Unmanned systems are proliferating rapidly around the world. While the U.S. remains the leader in UAS innovation, the Air Force must maintain its technological advantage through development of new systems to counter adversary unmanned systems. The DoD recently began experimenting with SUAS in counter-UAS roles.

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9 "2014 Quadrennial Defense Review." http://www.defense.gov/pubs/2014_Quadrennial_Defense_Review.pdf

10 "Unmanned Aerial Vehicle (UAV) Market (2013 - 2018)." MarketsandMarkets.com.

11 "Small UAV Market by Trends (Mini, Micro, Hand Held UAV), by Propulsion (Hydrogen, Electric, Solar, Lithium ION), by Payload (NBC Detection, Telemetry Systems, Software Systems, Meteorology), by Application (Civil, Military, Security), by Region & by Country - Global Forecast to 2014 – 2019." MarketsandMarkets.com.

2. Strategic Planning Overview

2.1. Strategic Guidance

The 2014 Quadrennial Defense Review states: "Regional and global trends in the security environment, coupled with increasing fiscal austerity, will make it imperative that the United States adapt more quickly than it has in the past and pursue more innovative approaches and partnerships in order to sustain its global leadership role[12]." In 2015, the Air Force Future Operating Concept (AFFOC) proposed solutions to how the Air Force forces will deliver responsive and effective Global Vigilance, Global Reach, and Global Power in an anticipated 2035 environment. The development and use of SUAS as a strategic instrument in future environments is the type of innovative approach the QDR and AFFOC envision. If executed properly, SUAS will provide a wider range of global capabilities via an affordable and sustainable medium.

SUAS provide unique solutions to rebalance the force for a broad spectrum of conflicts within the constraints of a fiscal environment. With new CONOPS and concepts of employment (CONEMPS) to address complex security challenges, both manned and unmanned material solutions must receive equal consideration during requirements development and the acquisition process. Reliability and sustainability of the desired end state capability are major considerations in the decision of whether a manned or unmanned (or a combination of both) solution is the appropriate choice. Enhancing or augmenting high-value manned platforms with low cost SUAS enables the Air Force to achieve a synergistic strategic focus by leveraging economies of force and cost efficiencies in a fiscally constrained environment.

2.2. Air Force Strategic Planning Document Hierarchy

The Air Force Strategy, *America's Air Force: A Call to the Future,* outlines strategic Air Force direction to ensure continued delivery of effective and responsive Global Vigilance, Global Reach, and Global Power for America over the next 30 years.

The Strategic Master Plan (SMP) operationalizes the Air Force Strategy by providing authoritative direction for service-wide planning and prioritization on a 20-year timeline. Its goals and objectives guide the four main SMP Annexes, as well as Core Function Support Plans (CFSPs) and other Flight Plans. These four SMP Annexes—the *Human Capital Annex*, the *Strategic Posture Annex*, the *Capabilities Annex*, and the *Science and Technology Annex*—provide more specific guidance and direction in alignment with the SMP goals and objectives to inform resource decisions.

Informed by the current 20-Year Resource Allocation Plan and proposed changes derived from guidance and direction in the SMP Annexes, senior leaders hold an annual Planning Choices Event that results in the following year's 20-Year Resource Allocation Plan. This 20-year plan is set against a projected fiscal topline. The first 10-year segment of the plan will receive additional scrutiny to ensure it provides the Air Force a "10-Year Balanced Budget," the first five years of which will be used to build the next POM.

The CFSPs apply subject matter expertise to support the goals and objectives in the SMP and SMP Annexes, and provide input to the Planning Choices Event. Flight Plans, such as this one,

12 "2014 Quadrennial Defense Review." http://www.defense.gov/pubs/2014_Quadrennial_Defense_Review.pdf

provide more detailed information to inform Air Force senior leaders. Flight Plans must align with Air Force Strategy and SMP goals and objectives (see Appendix B). The CFSPs and associated Flight Plans also inform future iterations of the SMP and its Annexes. This process ultimately generates a strategy-aligned, resource-informed plan for the Air Force. Through this framework, the SUAS Flight Plan will inform the entire strategic process as depicted in Figure 5.

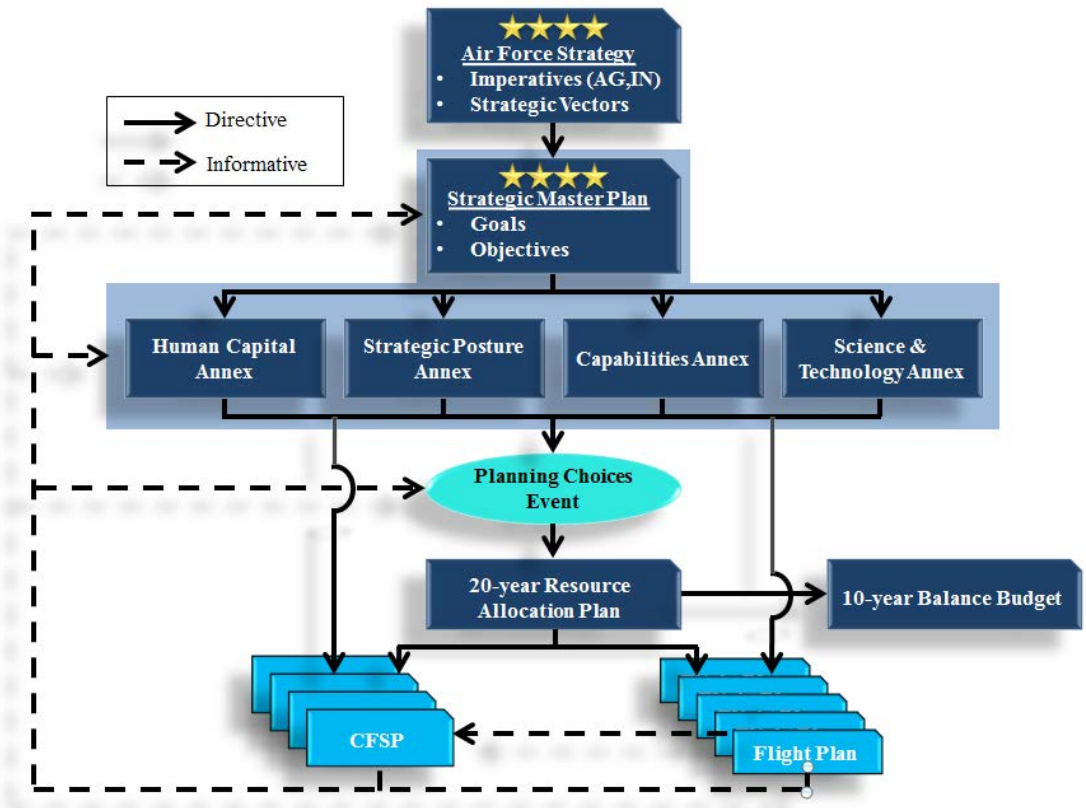

Figure 5: New Strategic Planning Documents

2.3. Considerations

There are numerous areas requiring significant executive level discussion. From system attributes to policy level recommendations, the following should be considered at the beginning of system development. Each area will effect or be affected by growth in SUAS.

2.3.1. Autonomy

Over the next 20 years, autonomy advances will mitigate "lost link" situations while enabling loyal wingman aircraft to fully integrate with manned aircraft, RPAs, and other SUAS. Additionally, semi-autonomous operations will transform the concepts of swarming and multi-aircraft control (MAC) allowing single operators to task and manage multiple SUAS within the battlespace. Loyal wingman differs from swarming in that SUAS will autonomously accompany, and thereby become an extension of, another aircraft to conduct missions across the Range of Military Operations (ROMO) such as: ISR, air interdiction, counter IADS, offensive counter air, C2, and weapons hosting. For swarming, machine-to-machine interfaces and advanced collaborative systems of systems will enable SUAS to function in self-forming rule-/

role-based airborne networks. These networks will have the ability to create virtual large array antennas or cyber and kinetic effects to saturate an adversary's IADS at a relatively low cost. "This acceleration in autonomy will accelerate the OODA (Observe, Orient, Decide, and Act) loop to provide critical information to the decision maker orders of magnitude faster than humans and will be crucial in future combat scenarios against a high-tech adversary."[13]

The distinction between "automated" and "autonomous" is an important one with the latter being widely misunderstood as evidenced by the contention that current platforms operate autonomously when they are largely automated even during lost link situations. When a UAS is controlled remotely, it is automated rather than autonomous. As stated in DoDD 3000.09[14], the USAF continues to plan for "man-in-the-loop" operations while pursuing increased autonomous functionality to reduce manpower requirements through MAC (see Figure 6). Additionally, onboard automation meant to streamline system, sensor, and analytical tasks is essential to collect, process, exploit and disseminate actionable intelligence, not just raw data. The ability to task a large number of assets with strategic tasks while retaining selective control of individual nodes will also be essential for future Air Force roles and missions. As such, these advancements will require a selectable level of autonomy to adhere to mission-specific and policy driven requirements and "future-proof" DoD investments[15].

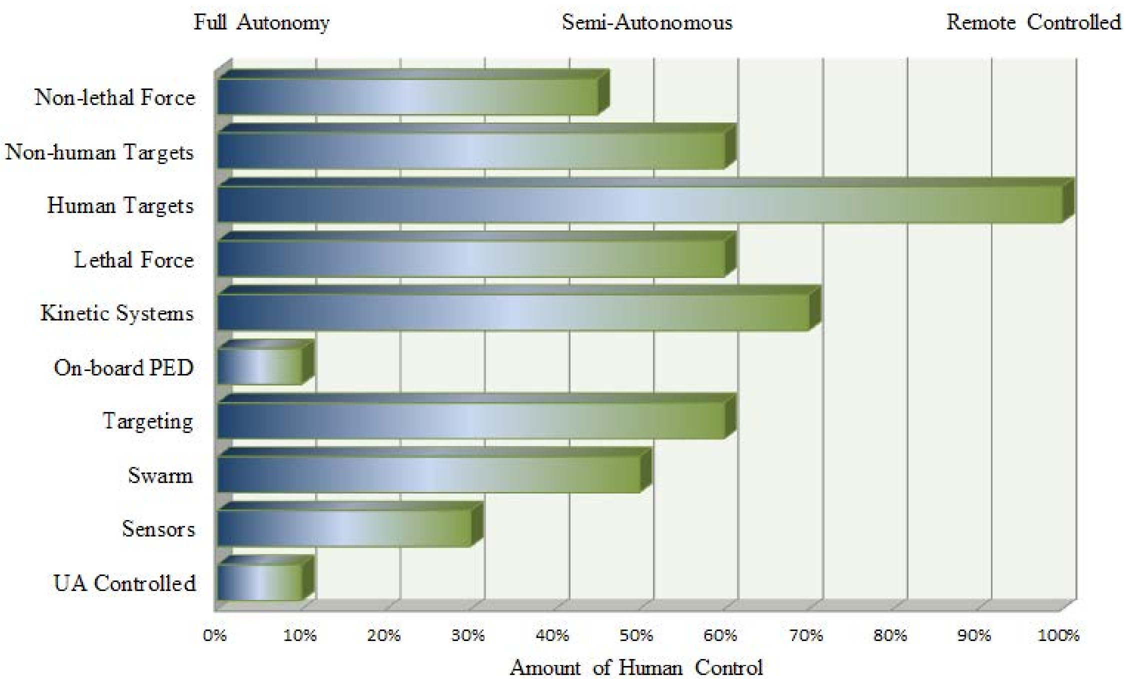

Figure 6: Notional Sliding Scale of Autonomy

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13 "Unmanned Systems Integrated Roadmap: FY2013-2038, Department of Defense." Reference Number: 14-S-0553. 40-1. http://www.defense.gov/Portals/1/Documents/pubs/DOD-USRM-2013.pdf.

14 DoDD 3000.09. "Autonomy in Weapon Systems." 21 November 2012. http://www.dtic.mil/whs/directives/corres/pdf/300009p.pdf.

15 Joint Air Power Competence Centre. "Remotely Piloted Aircraft Systems in Contested Environments." September 2014. 104. https://www.japcc.org/portfolio/remotely-piloted-aircraft-systems-in-contested-environments-a-vulnerability-analysis/

Autonomy "onboard" the UAS is only the beginning. Nearly all unmanned systems require some active control element for basic operations and behavior that affects communications, manpower, and system effectiveness. Personnel remain one of the largest cost drivers in the DoD today. Significant manpower is required to direct UAS during mission performance, collect and analyze data, plan and re-plan mission details, and conduct maintenance in conjunction with multiple launches and recoveries. The drive to autonomy must work in concert with the necessity to increase operational effectiveness while reducing budgets and manpower. Therefore, innovations that create manpower efficiencies will be essential as unmanned systems proliferate globally. Capabilities-based assessments for future autonomy should capture lifecycle manpower savings and identify cost-saving offsets. These offsets will drive neutral or negative life-cycle cost estimates (LCCE) when considering automation costs against manpower cost savings[16].

The SUAS Flight Plan advocates for continued innovation and investment in autonomy to augment and enhance human capabilities to maintain an affordable force structure and effectively achieve airpower economies of scale in an increasingly complex environment.

2.3.2. Data Protection

Encryption of SUAS C2 and sensor data links is critical for freedom of navigation and protection of data and other sensitive information. The DoD developed standards for the encryption and management of SUAS C2 communications as well as still and motion imagery. Type 1 validated encryption is required for processing classified communications, and Federal Information Processing Standard (FIPS) 140-2 at a minimum, must be used for processing unclassified communications[17]. Future encryption innovation will provide products that are quicker to market, have greater coalition interoperability, and improve key management[18]. Faster encryption product certification will facilitate lower life cycle costs and commensurate lower logistical costs while aiding in coalition interoperability.

2.3.3. Data Exploitation

As SUAS become more prevalent globally, their ability to collect increasing amounts of intelligence data would create challenges for current PED systems. In order to deal with the quantity of intelligence data generated by sensors and systems, improved standardized analytic algorithms must be developed. Currently, an inordinate number of PED personnel are required to process and exploit one MQ-1

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16 Department of Defense. "Unmanned Systems Integrated Roadmap: FY2013-2038." Reference Number: 14-S-0553. 29. http://www.defense.gov/Portals/1/Documents/pubs/DOD-USRM-2013.pdf.

17 DoDI S-4660.04. "Encryption of Imagery Transmitted by Airborne Systems and Unmanned Aircraft Control Communications (U)." 27 July 2011.

18 Department of Defense. "Unmanned Systems Integrated Roadmap: FY2013-2038." Reference Number: 14-S-0553. 16. http://www.defense.gov/Portals/1/Documents/pubs/DOD-USRM-2013.pdf.

Predator or MQ-9 Reaper mission. The high probability of hundreds or even thousands of future SUAS carrying out similar ISR missions would overwhelm the current PED architecture.

As advances are made to intelligence collection methods, complementary technological and process advances must follow suit to enable processing and exploitation of the increasing volume of intelligence data. To reduce manpower demands, technology breakthroughs in autonomous, onboard, and networked PED must be made. For now, a human decision maker will remain in the exploitation process; however, there is a critical need for machine-aided manpower to bring about time efficiencies within the PED enterprise. By improving automated processes and data exploitation methods, both manpower requirements and OODA-loop cycles will be reduced enabling an increased operations tempo with scaled down PED growth. However, before PED can be funded and manned to support SUAS, requirements need to be validated.

2.3.4. Selective Innovation

National military strategy and joint concept documents cite technical innovation as the key to future capability improvements. However, due to future budget constraints, many of these future mission needs will be met by funding capability improvements that exploit existing system architectures. This approach can range from the simple – modifying a sensor to improve data flow – to the more complex – applying standard message set architectures to improve interoperability. In this fiscally-constrained environment, the Air Force can maximize existing investments while also evolving new SUAS capabilities.

2.3.5. Battlespace Evolution

Another area ripe for modernization is the improvement of existing CONOPS and development of new CONOPS and CONEMPS. Newly innovative approaches to unmanned systems development will better address future battlefield requirements. SUAS offer innovative ways of thinking about the future battlespace with smaller, lighter, faster, and more maneuverable capabilities. Additionally, higher risk environments can be exploited by SUAS in ways not suitable for manned platforms. The absence of a pilot reduces or eliminates the need for armor, redundant flight controls, and life support systems allowing for greater size, weight, and power as well as payload cooling (SWaP-C) trade space and improved operational capabilities[19].

> *"…[A] fleet of low-cost, disposable platforms could survive through attrition rather than through expensive, exquisite capabilities."*
>
> **-Unmanned Systems Integrated Roadmap FY2013-2038**

The UAS industry continues to make remarkable gains in miniaturization of sensors and power plant efficiencies enabling successful migration of capabilities from larger platforms to smaller, more cost-effective SUAS. The miniaturization of synthetic-aperture radar (SAR) is one notable example now employed on the 45-pound Scan Eagle. The next generation of

19 Department of Defense. "Unmanned Systems Integrated Roadmap: FY2013-2038." Reference Number: 14-S-0553. 18. http://www.defense.gov/Portals/1/Documents/pubs/DOD-USRM-2013.pdf.

SUAS must also consider mitigation of platform limitations, including size, power, and range. These limitations can be reduced through a combination of technology advancements and CONOPS innovation.

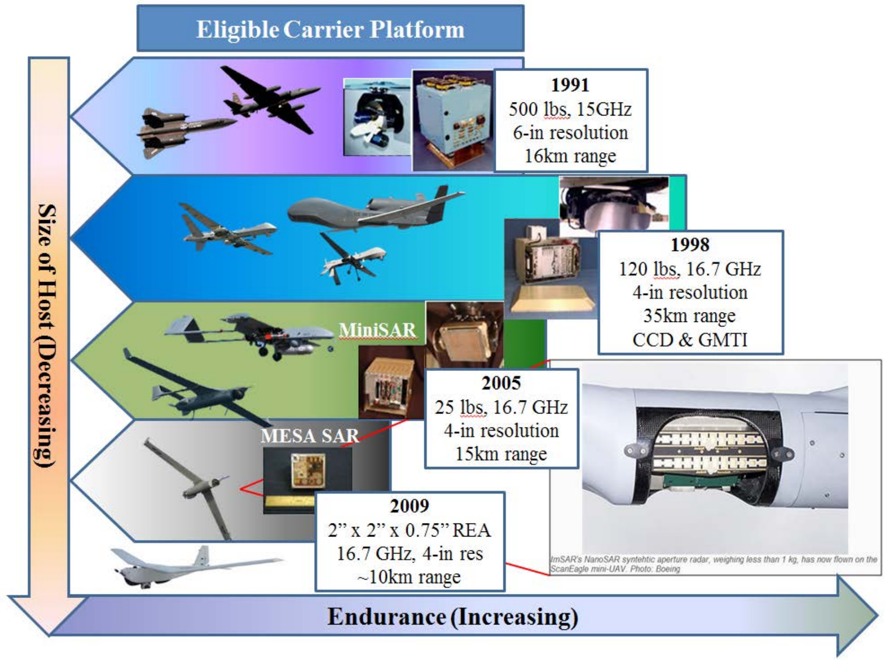

Figure 7: An Example - Miniaturization of SAR

2.3.6. Airspace Integration

The Air Force, through the Policy Board for Federal Aviation (PBFA), will continue to work with the Federal Aviation Administration (FAA) to achieve routine UAS access to the NAS in order to meet training needs. Current FAA regulations, procedures, and standards specifically addressing SUAS flight operations significantly restrict how, when, and where flights may occur. While RPA and SUAS force structure continues to grow, efforts to achieve increased NAS access have lagged behind demand. Current SUAS access continues to be limited by FAA regulatory flight rules. Similar limitations and prohibitive regulatory issues exist in International Civil Aviation Organization (ICAO) airspace and must be considered in all NAS discussions.

> *"DOD UAS require routine NAS access in order to execute operational, training, and support missions and to support broader military and civil demands. UA will not achieve their full potential military utility to do what manned aircraft do unless they can go where manned aircraft go with the same freedom of navigation, responsiveness, and flexibility."*
>
> **-Unmanned Systems Interoperability Roadmap FY2013-2038**
> **Office of the Secretary of Defense**

SUAS flight operations are restricted to special use airspace (restricted or warning areas) without FAA-mandated safety mitigations, such as chase aircraft or certificates of waiver or authorization (COAs). These regulatory requirements limit routine access to the NAS for training, research and development, and test and evaluation, which has complicated development of innovative SUAS capabilities. To ensure adequate access to airspace, the Air Force must strengthen existing FAA partnerships with a focus on ground-based sense and avoid (GBSAA), airborne sense and avoid (ABSAA), and airspace policy and procedures changes. U.S. airspace regulations and policy will inform international and foreign national airspace policy through continued engagement with partner nations[20].

2.3.7. Manned-Unmanned Teaming (MUM-T)

The ability to link and merge unmanned systems (air, ground, and sea) into teams of manned and unmanned systems is the result of both technological advances and military necessity. An essential Air Force goal is to continue development of MUM-T joint operational concepts to provide flexible options to improve ISR core competencies in A2AD environments, counter-UAS requirements, and force protection of key assets. Integrating smaller, more agile manned-unmanned systems with existing capabilities will enable the Air Force and other Services to respond quickly to deter and defeat aggression (see Figure 8). MUM-T provides some of the following key capabilities:

- Defeating IADS from greater standoff distances at acceptable attrition rates.
- Expanding the capability for massed precision strike.
- Enabling movement and maneuver for projecting strategic effects.
- Establishing and sustaining the assured lines of communications while expanding electromagnetic control.
- Protecting austere locations with operational and strategic implications.

Providing persistent surveillance to detect and neutralize threats and hazards within Highly Contested Environments (HCE)[21].

20 "United States Air Force RPA Vector: Vision and Enabling Concepts 2013-2038." 17 February 2014. 27-8.

21 Department of Defense. "Unmanned Systems Integrated Roadmap: FY2013-2038." Reference Number: 14-S-0553. 19.

Figure 8: Conceptual Teaming

2.3.8. Treaty Compliance

Past use of armed UAS was vetted through the DoD Compliance Review Group (CRG) and determined to be compliant with the Intermediate Range Nuclear Forces Treaty (INF Treaty). Future SUAS development should be reviewed by the DoD CRG at the earliest stages to determine any arms control limitations or implications that may exist based upon treaties in force at the time. Also, early coordination with Air Force Foreign Clearance Program Managers will ensure protection of Service equities during future arms control treaty negotiations.

3. Requirements and Programmatics

3.1. The Case for SUAS

The exponential proliferation of UAS continues due to increasing utility and demand. For the last decade, conflicts in Iraq, Afghanistan, and other operating areas have furthered UAS advancement, particularly in the ISR mission set. However, UAS use in other domains is also on the rise as they continue to provide exceptional situational awareness and mission performance while minimizing workload and risk to both civilian and military personnel.

Not all UAS capabilities are unique when compared to manned platforms, but it is important to highlight that some requirements, or capability gaps, can better be met by unmanned systems. The benefits of unmanned platforms are twofold. First, removing the human can have performance advantages, allowing designs that would not otherwise be possible. SUAS are a great example of this, since almost by definition they are aircraft so small that a manned version of them would not be feasible. Removing the human from a vehicle can translate to smaller size, smaller signature, faster speed, greater endurance, more maneuverability, etc. While it is improbable to build a single air vehicle that can do all of these, removing the pilot from the aircraft opens up a whole set of design aircraft choices that have never previously been available. We have only begun to understand the possibilities.

The second advantage of taking the person out of the air vehicle is that the asset now can be put in harm's way without risking a human life. This enables a whole new set of potential CONOPs, including using it as an expendable asset (decoy, jammer, collector, kinetic strike, etc.) or accepting more risk that may result in loss of the air vehicle. The utility of this option decreases as the asset itself is more exquisite, critical, and harder to replace. A $1 billion bomber is probably not expendable under most conditions, regardless of whether or not there are people on board. However, SUAS have ample opportunities to exploit these two advantages of performance and risk.

More generally, The Department of Defense Unmanned Systems Integrated Roadmap: FY2013-2038 states that UAS are the preferred alternative to manned systems for missions that are characterized as dull, dirty, or dangerous[22]:

- **Dull** missions usually refer to those requiring long airborne durations to meet a customer's objective such as border surveillance, airborne communications relay/gateway, or pipeline surveying. "Dull" missions are not exclusive to unmanned systems, but their inherent capabilities of persistence, versatility, autonomy, reduced risk to human life, and lower operational cost makes them very appealing.

- **Dirty** missions have the potential to expose personnel to hazardous conditions. A prime example includes chemical, biological, radiological, and nuclear detection missions. Unmanned systems can perform these missions with reduced risk of operator exposure.

- **Dangerous** missions involve high risk activities typically associated with a threat to both aircraft and crew. With technological advances in performance and automation, UAS greatly reduce risk to personnel by eliminating their exposure to dangerous activities.

In the past, SUAS have been procured and utilized to address limited, niche mission objectives. Despite the cost savings, short duration and minimal payload capacities stifled SUAS from consideration for critical operations when compared with larger manned and unmanned systems. As a result of growing SUAS interest in the commercial sector, these limitations are being rapidly addressed through industry research and development. For example, sensor payloads that once weighed more than most SUAS platforms have been miniaturized to only a few pounds with capabilities similar to their much larger variants. SUAS now represent the largest UAS growth area and these improved capabilities will resolve previous Air Force concerns for SUAS employment.

As SUAS technology develops, their battlefield role needs continuous evaluation to ensure maximum benefit to the warfighter. RPAs represent a good example of role examination and mission evolution in the current environment as they entered service as strictly ISR platforms. However, the operational concept of adding precise munitions to engage targets and minimize collateral damage quickly emerged and has become a mainstay RPA capability. Similarly, SUAS will evolve to fulfill identified capability gaps.

22 Department of Defense. "Unmanned Systems Integrated Roadmap: FY2013-2038." Reference Number: 14-S-0553. 20.

3.1.1. Speed of Deployment

In their current usage, SUAS ability to rapidly deploy is one of their greatest attributes. Once in place and with little or no assembly, the majority of systems can be launched quickly and utilized within minutes. In contrast, the majority of manned systems and RPAs could take hours or days to become operational. While technological developments have reduced the employment time for manned and RPA capabilities, small unit-level ISR and strike support can be more quickly supported with organically assigned SUAS capabilities.

3.1.2. Sensor Disaggregation

Continuous development of sensors requires agility in integration efforts. This can be complex in manned aircraft due to airworthiness certificates and in RPA due to proprietary hardware and/or software integration considerations. As a result of relative size and cost, SUAS can enable sensor development and corresponding airworthiness certification without larger system integration. When combined with a swarm of various sensors and platforms in a system of systems (SOS) approach, the disaggregation can achieve survivability through resiliency. Physically distributed sensors that fuse data can act as an array, conducting more precise geolocation or higher-fidelity sensing than might be possible with a single-point sensor and at lower cost. Additionally, distributing sensors among a swarm allows a heterogeneous mix of plug and play sensors that are suitable for the specific operating environment and potentially more cost effective. For example, the Air Force could use large numbers of low cost, low fidelity sensors to find potential targets followed by a smaller number of higher cost, higher fidelity sensors on faster, more responsive platforms to rapidly positively identify and precisely locate the targets. This might be a more cost effective solution than building single platforms that have to do it all on their own. The net effect of disaggregation is the distribution of capability across large areas or massing when necessary.

3.1.3. Affordability

The Air Force needs new strategies to break the cycle of ever increasing complexity, fragility, and cost. The resultant solution provides full capability but under large development horizons and at prohibitive costs. When development risks are dispersed among several lower-cost platforms, it is easier to suspend those that fail to achieve benchmarks while reallocating those resources to those that meet or exceed objectives. This provides several advantages to Air Force capability. As advanced weapon systems' costs continue to rise, procurement numbers fall simplifying an adversary's offensive and defensive solutions. The cost of current and projected programs has become our critical vulnerability. The Air Force must break the cycle of evolution that singularly focuses on increased platform technology that limits power projection capabilities.

> *"Instead of committing vast amounts of national treasure to overwhelm any and all potential adversaries, we will develop innovative, lower-cost options that demand high-cost responses. If it costs markedly less for us to defeat a missile than it does for the adversary to build and launch it, the strategic calculus changes significantly."*
>
> **-America's Air Force: A Call to the Future, July 2014**

3.1.4. Adaptability

SUAS provide strategic agility through adaptability. The ability to adapt and respond faster than our potential adversaries remains a key tenet to the future of Air Force strategy[23]. Through lower-cost platforms built around the payload or common platforms that can accommodate modular payloads, disparate capabilities can be advanced or shelved to meet emerging requirements across the ROMO, allowing the Air Force to maintain a robust and flexible globally integrated ISR capability – "Maintaining the ability to provide an effective and vigilant stance through broad-area, global ISR and then rapidly transition to more focused warfighter collection requirements demands elasticity in ISR capability[24]."

Right now, a 'combat system' is an aircraft that has various sensors, communications, munitions, etc. onboard. The aircraft is the weapon system. However, sensor disaggregation expands the weapons system concept to prioritize 'payloads over platforms.' This view of the combat system shifts thinking from the aircraft as a static weapon system over time to a truck whose payload can be rapidly upgraded over the same horizons; and swarms allow further expansion. Now payloads are on a suite of different air vehicles of various sizes rather than integrated into a single aircraft. So the 'weapon system' is the swarm, not any single aircraft. This concept obviates SWaP-C limitations of a single aircraft when a component needs to be upgraded. Rather, a new air vehicle is added to the swarm and any number of modular trucks of various sizes and shapes can be utilized to achieve the required SWaP-C. The new payload must be integrated electronically, of course, but this is necessary regardless of the hosting platform. Additionally, the swarm's reliance on a wireless network must be designed into the system at the beginning. Despite these challenges, the benefits of cost, mass, and resiliency in addition to rapid upgrade capabilities enables the swarm to adapt to new environments and emerging requirements much faster than today's systems.

3.2. SUAS Requirements Pedigree

Service operational capability staffs are beginning to see SUAS applications in new mission areas with corresponding growth in payload effectiveness, platform endurance, and concepts of operation. Many existing capabilities were developed using the deliberative requirements and acquisitions processes while others were acquired in response to validated capability gaps via Joint Urgent Operational Needs (JUONs) and service-specific Urgent Operational Needs (UONs)[25]. In recent years, theater-requested SUAS capabilities were mostly developed by the rapid acquisition process and funded by single-year OCO funds. While these rapidly acquired SUAS capabil-

23 "America's Air Force: A Call to the Future." July 2014. 8.

24 "America's Air Force: A Call to the Future." July 2014. 15.

25 CJCSI 3170.01. "Joint Capabilities Integration and Development System." 23 January 2015.

ities met immediate warfighter needs, the resulting systems were not fully interoperable across their specific Joint Capability Area (JCA).

Sustainment of disparate legacy systems has proven to be more difficult and inefficient when considering modernization and lifecycle costs to meet baseline requirements and budget authorities. As contingency operations begin to wane, future SUAS concept development should follow the deliberate Joint Capabilities Integration and Development System (JCIDS) process to realize the benefits of full design capability and life-cycle requirements[26]. As the deliberate JCIDS process is implemented, investigating the requirements documents and programs of record (POR) already approved and validated in other Services is critical to efficiently fielding new capabilities within the Air Force. These already approved systems may be available in the DoD inventory to meet operational gaps and save years of requirements development. As SUAS become institutionalized, the Air Force will achieve greater cost savings, improved interoperability and logistics, as well as standardized joint tactics, techniques, and procedures (TTPs).

SUAS technology and capability continues to mature thereby facilitating new operational concepts to meet current and emerging Air Force gaps. During future SUAS development and acquisition, the Air Force should procure data rights and include design modularity as a Key System Attribute (KSA) in JCIDS requirements documents. This new KSA is essential to establishing an adaptable, agile SUAS architecture to meet rapidly changing combatant commander requirements. Modularity will enable rapid payload fielding, minimize integration costs, and permit warfighters to tailor SUAS capabilities to meet emerging mission demands in an expeditious manner.

3.3. Acquisition Initiatives

At present, the Air Force has no strategic programming actions to acquire new SUAS. If the Air Force is to leverage the potential of SUAS, it is critical that key capabilities be demonstrated as effective and affordable alternatives for critical mission sets. Translating gap analysis into validated requirements will lead to establishing programs of record for first-generation operational SUAS. The foundational NextGen SUAS requirement should be modular to enable prosecution of a variety of missions. Additionally, affordability remains a critical component to support a strategy of massing SUAS to accomplish multi-role effects across the full spectrum of operations. Finally, all SUAS should be engineered with exportability requirements already being considered and met in order to protect U.S. technology. Inserting this attribute late in the acquisition cycle can be cost prohibitive.

Currently, any unit that desires a SUAS and has the financial means to procure one may do so without coordination outside their organization (provided they fall below established financial thresholds). As the Air Force begins developing and acquiring new SUAS platforms, we must recognize this ad hoc procurement model is an impediment to establishing a healthy, efficient, and affordable future SUAS fleet. Training, sustainment, and future development must be anticipated and built in at the beginning of the acquisition process. Additionally, a single SUAS program office is more advantageous and affordable for procurement and sustainment, as well as life cycle pre-planned product improvements (P3I), version control, publication management, accountability, reporting, and system demilitarization and disposal. The absence of centralized programmatic control has led to a mix of capabilities that are non-interoperable, non-transferra-

26 Department of Defense. "Unmanned Systems Integrated Roadmap: FY2013-2038." Reference Number: 14-S-0553. 20-1.

ble, and unsustainable. These shortfalls will continue until a SUAS SPO, tied to a Lead MAJCOM, is officially established. At a minimum, the focus on future SUAS requirements development should include: affordability, modularity (hardware), interoperability (software), growth capacity, autonomy, persistence, weaponry, datalink/frequency spectrum, and the ability to operate in all environments.

> *"Designing systems to easily accept technological improvement capabilities and support multiple mission needs will be increasingly important."*
>
> **-Unmanned Systems Integrated Roadmap FY2013-2038**

4. Key System Attributes

New SUAS technologies are expected to exponentially increase over the next few years as NAS integration is expanded and commercial applications are recognized. Expansion of new materials, power plants, sensors, and automation are already evident in the marketplace. While new technologies provide ever increasing possibilities for SUAS, they also present challenges. SUAS emulate characteristics found in the modern day cell phone with technical obsolescence occurring every 18-to-24 months. This short life cycle not only outpaces acquisition cycles, but also budget planning processes. Future systems must be developed with deliberate mitigation plans for shortened life spans while considering other factors such as affordability, interoperability, modularity, resiliency, security, persistence, autonomy, position-navigation-timing (PNT), weaponry, and connectivity.

4.1. Affordability

Costs can be reduced through various methods to include inter-service teaming. With budgetary constraints and the resulting extension of legacy platforms, SPOs can achieve significant cost savings using should-cost analysis methods for resource alignment[27][28]. Through targeted affordability initiatives, SUAS costs are projected to continue decreasing. Additionally, these capability gaps should be filled by designating JCIDS "for Joint Interest" to coordinate other Services' existing requirements and acquisition efforts while using fewer resources. Today, manned aircraft satisfy most operational requirements, however with SUAS, many of these mission sets can be accomplished in a more safe and efficient manner. While SUAS are generally considered cost efficient, the technology required to resolve some of today's stringent regulatory compliance issues may negatively affect system affordability[29]. New technologies continue to emerge that ease the regulatory burden while driving down these compliance costs. Accurate cost modeling early in the requirements development phase will be the key to effective program management throughout the life cycle of SUAS.

27 Carter, Ashton B., Under Secretary of Defense, Acquisition, Technology, and Logistics, "Should-cost and Affordability Memorandum":http://www.acq.osd.mil/docs/Should-cost%20and%20Affordability.pdf.

28 Carter, Ashton B., Under Secretary of Defense, Acquisition, Technology, and Logistics, "Implementation Directive for Better Buying Power – Obtaining Greater Efficiency and Productivity in Defense Spending": http://www.acq.osd.mil/docs/USD(AT&L)_Implementation_Directive_Better_Buying_Power_110310.pdf.

29 "United States Air Force RPA Vector: Vision and Enabling Concepts 2013-2038." 17 February 2014. 80.

4.2. Interoperability and Modularity

Most of today's SUAS were fielded as stove-piped solutions to meet immediate warfighter needs through the Quick Reaction Capability (QRCs) process. This typically involved all components of the SUAS being provided sole-source by the original equipment manufacturer (OEM). Generally, these systems consist of proprietary equipment comprised of the unmanned aircraft vehicles (UAVs), control segment (CS), integrated payload, and LRE. These SUAS proved responsive and valuable in filling immediate functional gaps, but were not sustainable or affordable primarily due to limited procurement and rapid technology obsolescence. The result of continuous acquisition of "one-off" systems led to inefficiencies in maintenance and modernization. Additionally, the lack of modularity and limited spare part supplies drove the need to procure complete new systems when only one component of the system needed repair or replacement.

Competition from a variety of vendors facilitates more diverse options at significant cost reductions. The concept of modularity also encourages payload exchange between different UAs and enables rapid integration of new payloads. Additionally, an open architecture for a common CS would bring additional vendors into the marketplace and ultimately reduce procurement costs. Likewise, a single standardized solution for initial and sustainment CS training would reduce the time-to-train thereby expediting inter-platform operational employment to develop a more experienced base of SUAS cadre. Finally, from a logistical standpoint, modularity provides a wider range of parts availability while reducing costs to operate, maintain, and sustain SUAS platforms (see Figure 9).

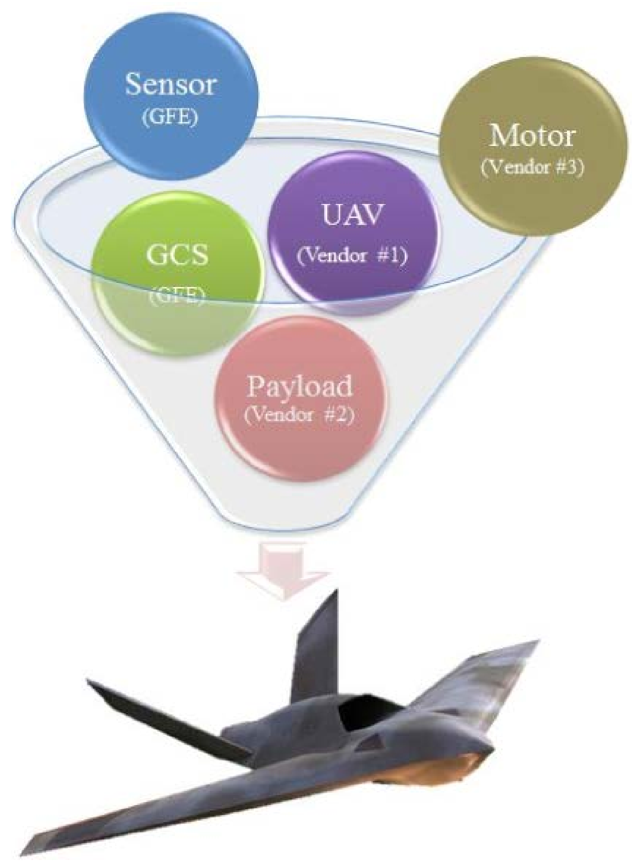

Figure 9: SUAS Modularization from Multiple Sources

Consideration should also be given to joint interoperability from acquisition through operations. Per-unit costs are significantly reduced with strategies that enable large quantity purchases. Additionally, interoperability and inter-service training become more seamless and efficient with a DoD-common configuration. Finally, this "best practices" model allows cross-service integration of new capabilities. All in all, joint interoperability avoids the unnecessary costs of procuring duplicative systems between Services while preserving unique payload needs with plug-and-play common architectures.

4.2.1. Interoperability

All future systems will benefit from increased interoperability. Due to expected high numbers of SUAS, the concept of joint interoperability is integral to development of SUAS capabilities. U.S. military forces engage and interact on the battlefield as a combined force. Therefore, SUAS must be designed to function in that fashion from their inception. This includes interoperability for networks (internal/external), command and control, and near real-time ISR dissemination. Within the joint force, SUAS interoperability should be "universal" to the extent that missions are scheduled to achieve inter-Service intelligence needs while avoiding duplicative asset allocation. Additionally, SUAS commonality and joint interoperability enables the rearming, refueling, and re-launching of any SUAS on the battlefield by any warfighter regardless of Service affiliation.

To achieve this level of interoperability, strict DoD standardization of unmanned systems must be implemented to exploit universal graphic user interfaces (GUIs), network architecture and security designs, and encryption protocols. Additionally, system design should be flexible enough to accommodate transition between theaters where frequency allocations and operational capacities vary. If adopted by the enterprise, these system standards will enable all participants to achieve information assurance, communications resilience, and protection from interception and spoofing.

4.2.2. Modularity

A modular design concept for SUAS hardware and software is one of the most essential enabling technologies for interoperability. Modular design will positively affect affordability, versatility, adaptability, and sustainability; and though it has yet to be incorporated into Air Force SUAS, it should be a highly prioritized requirement for future systems.

Hardware modularity should begin with a core central fuselage and processor with all other parts being interchangeable for specific missions or operations (see Figure 10). While not intended to be prescriptive, many years of operations and the resulting lessons learned suggest consideration of the following platform attributes: high speed wing, high lift wing, high speed engine, long endurance engine. Additionally, payloads with the following capabilities are in high demand: EO/IR, SIGINT, hyperspectral, electronic warfare, and kinetic options.

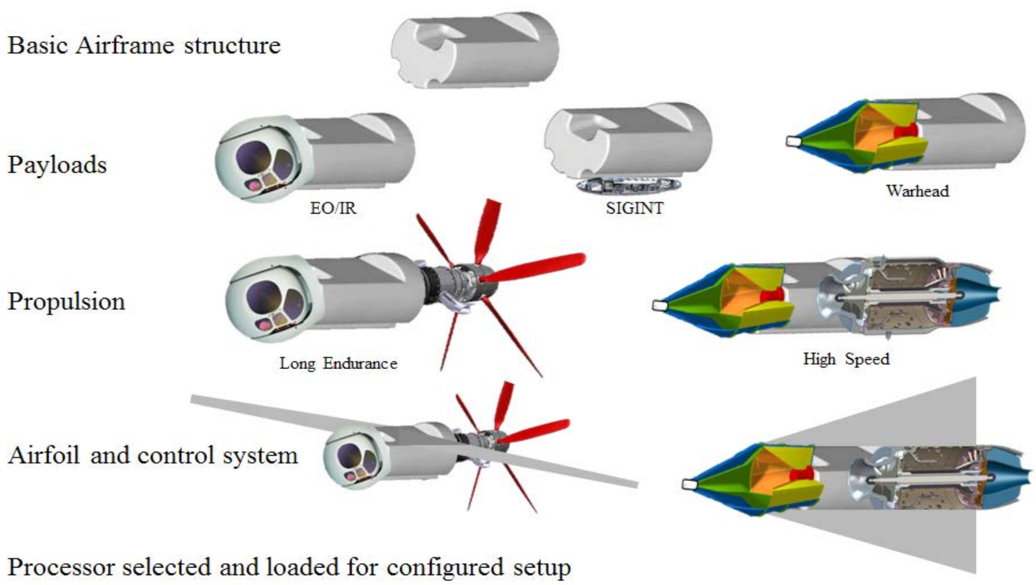

Figure 10: Notional SUAS Modularity

The modular software concept is best demonstrated by the relationship between a common operating system and the applications it runs, much like today's smartphones. For SUAS, software segregation for aircraft control, payload operation, systems integration, and operational management is essential for flexible, sustainable, and affordable future systems. This design concept enables the incorporation of new payloads, wings, and propulsion systems without requiring comprehensive software rewrite each time a component changes. This concept is enabled by an open architecture, baseline software suite with common control and service buses. Additionally, a corresponding app for each new modular piece of hardware would permit seamless integration and utilization.

A modularly designed SUAS provides numerous advantages. For example, one key advantage of a modular system is the ability to rapidly field new capabilities while enhancing logistical sustainment across services employing the platform. Also, accelerated integration of new capabilities will result from payload designers building to specific form-fit-function and software standards. The ability to program new software to interface with the core software framework will expand competition and increase available capability apps while reducing costs.

4.3. Communication Systems, Spectrum, and Resilience

SUAS must contend with many challenges within the radio frequency (RF) environment. These challenges include the availability of communication links, the amount of data those links can support, the availability, authorization, and allocation of RF spectrum, and the resilience of all RF subsystems against spoofing and interference (most prominently electromagnetic). The Air Force must attend to these challenges while improving interoperability requirements in support of Combatant Commanders. Though autonomy may obviate or at least alleviate some of these issues, most platforms will require some level of "man-in-the-loop" for operational control and mission data distribution. New technology is helping operators migrate from hard-wired terrestrial cables to over-the-air electromagnetic spectrum (EMS), acoustical, or optical mediums. These options will facilitate information sharing for historically isolated and independent systems to provide input to the common operating picture (COP). To improve on current legacy shortfalls, the Air Force should no longer procure or maintain SUAS communication infrastructures characterized by proprietary or stove-piped solutions, lack of interoperability, and inability to distribute data to consumers. Accordingly, the DoD Unmanned Systems Integrated Roadmap accurately captures the current issues with UAS communication infrastructure[30]:

- Poor Global Connectivity
- Costly Satellite/Network Contracts
- Stove-pipe Infrastructures
- Poor Information Sharing

The Air Force will have to address these issues as SUAS capabilities expand to resemble larger UAS to avoid the same pitfalls. From a spectrum limitation standpoint, dynamic spectrum/frequency allocation is one of the keys to the future. Defense Advanced Research Project Agency's (DARPA) Next Generation project and its follow-on Wireless Network after Next (WNaN) program demonstrate the feasibility and potential of dynamic spectrum access (DSA). DSA offers the ability to change frequency bands to more favorable ones based on "cognizant" radios sensing actual use of certain bands by other adjacent spectrum-dependent systems. While promising technology, a recent Air Force Scientific Advisory Board provided a cautionary note that DSA is still a ways from being a mature technology. Developmental challenges include susceptibility to countermeasures, costs of integrating with existing systems, developing regulations, standards and policies, and co-site interference[31].

4.3.1. Electromagnetic Spectrum and Bandwidth Management

Frequencies and bandwidth demand will increase with the growth and proliferation of UAS yet there is a limited amount of frequencies available to support operations. Prior planning between military UAS operators, frequency managers, and airspace control authorities will be critical to ensure approved UAS flight operations. Two methods used to ensure frequency availability: geographic separation and timesharing. Geographic separation is using distance or natural terrain to prevent signal overlap while operating on the same frequency at multiple locations. Timesharing provides separation of frequencies by schedule. Addition methods of spectrum sharing include Code-Division (i.e. CDMA) and Orthogonal (i.e. OFDM). Regardless of the method, as operations grow and expand, attention must be given to the amount of spectrum required to meet UAS operations before spectrum becomes a limiting factor.

4.3.2. Combined Spectrum Management Cell (CSMC)

Training within the Continental United States (CONUS) has been impacted by spectrum oversaturation while trying to meet IQT, CT, and OT&E simultaneously. While this has presented

30 Department of Defense. "Unmanned Systems Integrated Roadmap: FY2013-2038." Reference Number: 14-S-0553. 40-1. http://www.defense.gov/Portals/1/Documents/pubs/DOD-USRM-2013.pdf.

31 Department of Defense. "Unmanned Systems Integrated Roadmap: FY2013-2038." Reference Number: 14-S-0553. 50. http://www.defense.gov/Portals/1/Documents/pubs/DOD-USRM-2013.pdf.

a training challenge, it illustrates what could occur during SUAS operations within a limited area, such as a city center or areas involving several airspace authorities. UAS operators will be required to coordinate with the local frequency manager in garrison or the CSMC during contingency operations to coordinate SUAS frequency allocation. The Combined Task Force Commander or Coalition Force Commander will establish the CSMC and produce a Battlespace Spectrum Management (BSM) plan to address issues and assign frequencies[32].

4.4. Security

With the evolution of integrated sensors across multiple systems and networks, there can be multiple levels of security and accreditation required to operate new or modified SUAS. In addition to documenting the protection of system-organic technologies and information, there should be a greater emphasis placed on evaluating how both system software and hardware connect to operational networks. Program managers may benefit from considering a platform agnostic, sensor-specific approach to address security accreditation across multiple systems and platforms. As a result, not only will the system technology have sufficient pre-approved integrated security protocols, but the information collected by the sensor will receive the same level of security accreditation.

4.5. Encryption

A key element of ensuring the integrity and confidentiality[33] of the data transmitted via any means (terrestrial circuits, line-of-sight, or beyond line-of-sight) is encryption. Encryption can protect data from interception by adversaries attempting to gain access to sensor data, prevent spoofing of command and control links, or mitigate other malicious actions, intentional or unintentional, that could affect the validity of data or provide an adversary with information that benefits their efforts. Encryption has been in use in increasing degrees of complexity for many decades, with both commercial and defense applications. Likewise, DoD UAS employ various forms of encryption from both industrial sectors. Three most commonly known encryption types are variations of the Data Encryption Standard (DES), Advanced Encryption Standard (AES), and National Security Agency (NSA) Type 1. DES originates from the early 1970s from work by NSA and IBM to support protection of government computer systems. AES, published as a standard in 2001, is the successor of DES as standard symmetric encryption algorithm for U.S. federal organizations. It uses 128 or 256 bit blocks (vice DES 64 bit blocks), and is efficient in both software and hardware implementations when compared to DES. NSA Type 1 refers to an NSA-endorsed classified or controlled cryptographic item (CCI) required for classified U.S. government information. FIPS 140-2 encryption must be used for the processing of unclassified UAS communications.

In the future, encryption solutions need to be engineered into the exportable design to ensure coalition interoperability, ease of use, and simplified keying/rekeying alternatives. That includes the use of solutions that can be certified as Type 1 for lower levels of classification (i.e. Secret and below) as well as provide coalition use. Another benefit of certain Suite B implementations is the determination as non-CCI; hence, they do not require recovery if the SUAS is lost, crashes, etc. Finally, current cryptographic key material requires specific hardware such as the simple key

32 ACP 190(D). "Guide to Electromagnetic Spectrum Management in Military Operations: Combined Spectrum Management Cell (CSMC)." February 2013.

33 Federal Information Processing Standards (FIPS) Publication 140-2, 25 May 2001

loaders (SKLs) and cables (i.e. RS-232) to load the keys on the UAS. In the future, consideration must be given to non-CCI devices that can be key-loaded dynamically (i.e. over the air), given all the necessary authentications. These may include layered security to include biometric methods combined with passwords or other key options. The goal should be protecting the data and mission without unduly encumbering the SUAS operator.

4.5.1. Jamming / Interference

Even with careful planning and approved frequency allocation, SUAS remain subject to unintentional or intentional emissions that may degrade, obstruct, or interrupt the signal to or from the aircraft. The majority of SUAS operate in the L-Band or S-Band within the UHF spectrum, which makes them susceptible to interference from a vast range of emitters. Specifically, cellular signals are very close to the operating range of many SUAS and can not only be a potential source of interference, but active cellular jammers could inadvertently affect them as well. Rapidly reporting suspected interference to the local frequency manager in garrison or the CSMC while deployed will enable those spectrum managers to identify the source of the interference and then take action to reduce, eliminate, or avoid future incidents.

4.5.2. Protection

Data encryption during SUAS operations is important to protect the C2 and mission information being transmitted as well as to limit intentional beaconing or intrusion. Usually aircrews mitigate virtual hijacking by monitoring their assigned aircraft and recovering it quickly to prevent hostile interception. However, as the systems grow in capability to fly farther and become more autonomous, the requirement to ensure both data encryption and anti-jamming technology must be sufficient to safeguard SUAS operations. Currently, UA must have Line of Sight (LOS) with the SUAS Operator (SUAS-O) to zeroize any encryption, which presents an issue if an aircraft were to experience a loss of link (LOL). Under LOL conditions, the SUAS-O cannot make inputs to the aircraft and it could land outside of the aircrew's control. This constraint creates the potential for exploitation if the SUAS were sky-jacked by an adversary.

4.6. Persistent Resilience

Persistence is not meaningful without resilience. The former is the continuation of an effect; the latter is the ability for an application, system, or subsystem to react to problems in one of its components and still provide the best possible service. Together, persistent resilience is the ability of a persistent UAS to continue its mission with resilient components[34]. With SUAS, this effect can be achieved by redundant components or through sheer numbers where some attrition does not defeat the capability. To this end, the Air Force should incorporate resiliency into SUAS concepts and development efforts. Persistent resilience can be leveraged to enable self-healing and distributed networks of SUAS that will reduce vulnerability through redundancy. Operational challenges such as A2AD can be mitigated with SUAS due to numerical advantages, size, and relative low cost, preserving more expensive platforms to operate in a more traditional manner. SUAS can and should be a force multiplier across the entire spectrum of conflict.

34 Department of Defense. "Unmanned Systems Integrated Roadmap: FY2013-2038." Reference Number: 14-S-0553. 61. http://www.defense.gov/Portals/1/Documents/pubs/DOD-USRM-2013.pdf.

4.7. Autonomy and Cognitive Behavior

"Autonomous" SUAS today are rule-based automated platforms vice "free thinkers" in that they are fully preprogrammed to perform defined actions repeatedly and independently of external influence. This does not mean they are unmonitored, but rather, retain a man-in-the-loop concept, though they may self-steer or self-regulate. However, there is much work being committed to moving SUAS beyond pre-programmed mission execution to independent mission performance. The platform's autonomous performance is associated with mission outcomes that vary due to internal and external variables forcing the system to deviate from preprogrammed tasks. As this transition is made, laws and strategies must be developed and adjudicated to govern an effective and safe operational framework.

The special feature of an autonomous system is its ability to be goal-directed in unpredictable environments and situations. This ability provides a significant improvement over automated systems. An autonomous unmanned system will be able to make decisions based on its perception of the environment in combination with a set of rules and/or limitations – a capability that will be critical to future conflicts in more complex environments. In the short-term, the Air Force needs to address collision avoidance to ensure public safety and access to national airspace. The long-term vision for SUAS focuses on access to and survivability in the A2AD environment. SUAS characteristics such as size, weight, and low cost per unit create a cost-capability dynamic that better addresses counter-A2AD concept development than does our legacy manned and unmanned systems. Autonomy in unmanned systems has been identified as a key enabler, but specific pathways for the introduction of autonomy technologies have yet to be determined.

There are S&T development programs for autonomy underway in the Air Force as well as at DARPA and Johns Hopkins Applied Physics Laboratory. While applications of autonomy among the Services tend to be applied to a specific domain of interest, in many cases the underlying technology is applicable across the ROMO. For example, the Air Force is developing teaming technologies for airborne platforms, while the Navy and Marine Corps are applying similar technologies to ground and maritime systems. The Army has fielded a teaming capability for the AH-64D Apache attack helicopter and the MQ-1 Grey Eagle UAS. The Army has used this capability successfully to support operations in Afghanistan and is applying similar technology to ground-based robots. As DoD advances the state of the art in autonomy, industry and academia partnerships will be vital to successful execution. Investment to produce more affordable systems will allow unmanned systems to become ubiquitous on the battlefield[35]. To ensure better communication of ideas and concepts and avoid a misunderstanding of technology maturity, it is important to discern the complexity and evolution of autonomy.

- **Human-Machine Interface (HMI).** Words like "semi-autonomous," "supervised autonomous" or "fully autonomous" refer to systems that have a human in-the-loop, on-the-loop, or out-of-the-loop, respectively. In this context, autonomy refers to the HMI relationship.

- **Sophistication of the Machine.** "Autonomy" is also used to refer to the *level* of sophistication of the machine's relative "intelligence," which is actually a completely different dimension of autonomy than is HMI. Thus, the concept of a spectrum of intelligence evolves

35 Department of Defense. "Unmanned Systems Integrated Roadmap: FY2013-2038." Reference Number: 14-S-0553. 66-8. http://www.defense.gov/Portals/1/Documents/pubs/DOD-USRM-2013.pdf.

from something that is "automatic" to "automated" to "autonomous." Each has different levels of ingenuity and learning algorithms, but the type of human interaction is still the same.

- **Machine Performance.** In the third context, autonomy refers to the *type* of task the machine performs. In this sense, "autonomous" corresponds to the task assigned. Some tasks may operate autonomously such as altitude, heading control, or takeoff and landing, while others may remain fully under the control of the human operator. Thus, it is important to distinguish between tasks requiring automated or autonomous behavior from those that call for human operation.

This discussion is not exhaustive. The U.S. Air Force Chief Scientist released a more lengthy discussion of this topic in Autonomous Horizons[36].

> *"As the capabilities of autonomy increase (including the ability to handle a broader range of situations and uncertainty), it is anticipated that the need for human intervention will decline, however, it is likely that some level of human-system interaction will continue to be required for the foreseeable future."*
>
> **-Chief Scientist of the Air Force, in "System Autonomy in the Air Force," 2015**

4.8. PNT systems

In order to achieve increased autonomy in SUAS, sensors are required that can provide a more accurate perspective of their surroundings as well as the capacity to interpret those inputs so that they can respond appropriately to the situation. Additionally, SUAS should be designed to be untethered from human control. Navigation is an essential enabler for unmanned systems autonomy. Given the dependence UAS have on PNT, the platform will execute only as well as the accuracy of the system. Inaccurate PNT introduces error to air vehicle navigation and sensor cueing. Mission computers are continuously updated with position, air and ground speed, and drift angles so the system knows its location and can intelligently negotiate the best route while avoiding restricted areas or boundaries. Global Positioning System (GPS) is the current PNT system of choice for DoD military applications in conjunction with Selective Availability, Anti-Spoofing Module (SAASM) as directed by Joint guidance. SAASM enables systems to take advantage of a higher strength military GPS signal resistant to jamming and spoofing. While SAASM is an essential GPS improvement, other PNT options may increase operational resiliency.

Today, SUAS rely exclusively on the aircraft's knowledge of its location in time and space. For military and civil applications, unmanned systems' inherent dependence on PNT data creates a potential vulnerability. If a platform is unable to accurately fix its position, mission success will be degraded. Through intentional or unintentional jamming, spoofing, or equipment failure, operations could be degraded or completely denied. This vulnerability necessitates incorporation of redundant PNT capabilities. Redundancy can be achieved through sensor-aided navigation or by station relative position using other platforms' known position. Additionally, chip-scale atomic clocks and state of the art inertial navigation systems utilizing cold atom principals offer

36 Chief Scientist of the Air Force. "System Autonomy in the Air Force – A Path to the Future." Vol. I. http://www.af.mil/Portals/1/documents/SECAF/AutonomousHorizons.pdf?timestamp=1435068339702

low-drift PNT solutions in the event of GPS degradation or denial. PNT resilience is an essential enabler to ensure target prosecution and mission success when faced with GPS interference, especially in contested environments. Miniaturization of such systems and system-level network functions could also negate adversary GPS jamming effects[37].

4.9. Propulsion and Power systems

Flexible mission objectives for tomorrow's SUAS may call for long-range capabilities to maximize global reach, while others may require long-endurance for persistence over any point on earth. Additionally, Global Strike missions may require a propulsion system optimized for speed and payload. To support the expanding roles of SUAS, propulsion systems that are fuel-efficient or utilize renewable/alternative fuels are needed to increase platform speed and endurance as well as support various power-hungry SUAS payloads. Many of today's larger persistent systems rely on efficient forms of propulsion that are sustainable for long-endurance Global Vigilance missions. SUAS will require these same propulsion and power benefits in a smaller form-factor to break into main-stream Air Force roles and missions.

As technology for propulsion systems continues to evolve and improve, maintenance, sustainment, and lifecycle cost reduction will better enable bulk purchasing; a key element for future SUAS strategies such as swarming. Smarter systems should allow for diagnostics or logic-based tools to perform "virtual inspections", thereby reducing the time to troubleshoot and fix malfunctions. Propulsion health monitoring systems will enable just-in-time maintenance. Also, employing renewable biofuels that meet required fuel performance metrics may also reduce operating costs. The more resilient propulsion systems become, the more cost effective they will be, and the more cost savings they will provide[38].

AFRL Aerospace Systems Directorate (AFRL/RQ), working in collaboration with AFSOC, USSOCOM, and the Army, recently completed the design of a hybrid fuel cell power system for Group 1 SUAS which meets military ruggedness and reliability requirements tripling the endurance capability compared to a conventionally powered system. The AFRL Small Unmanned Renewable Energy Long Endurance Vehicle (SURGE-V) program's primary goal was to demonstrate that hybrid fuel cell power systems are a viable alternative to meet the propulsion and power needs of a fieldable hand-launched SUAS, while offering both the endurance and payload power only available to larger Group 2 and above systems. Although previous AFRL programs were successful in demonstrating the endurance benefit of fuel cell hybrid power systems for SUAS applications, they also demonstrated that a higher degree of ruggedness and reliability were required. The SURGE-V program successfully addressed both those issues and is currently moving toward demonstration and transition.

AFRL/RQ also is developing fuel cell hybrid power system and advanced battery technologies to extend the endurance and power for Group 1 attritable AL-SUAS applications. AFSOC intends to use these AL-SUAS to see below the weather, track multiple targets, increase target acquisition accuracy, and provide direct support to ground teams. The Air Force Small Business Innovation Research (SBIR) sponsored Air-Launched, Tube-Integrated Unmanned Systems (ALTIUS) program is expected to offer a four-fold (advanced battery technology) to six-fold (advanced fuel cell

37 "United States Air Force RPA Vector: Vision and Enabling Concepts 2013-2038." 17 February 2014. 69.

38 Department of Defense. "Unmanned Systems Integrated Roadmap: FY2013-2038." Reference Number: 14-S-0553. 65.

systems) increase in flight endurance despite challenges such as extended stowage, remote launch from a tube with little to no initial airflow, or operation over broad temperature and altitude ranges. Flight demonstrations for the ALTIUS persistent AL-SUAS technology began in late-FY15 and are anticipated to continue through FY16[39].

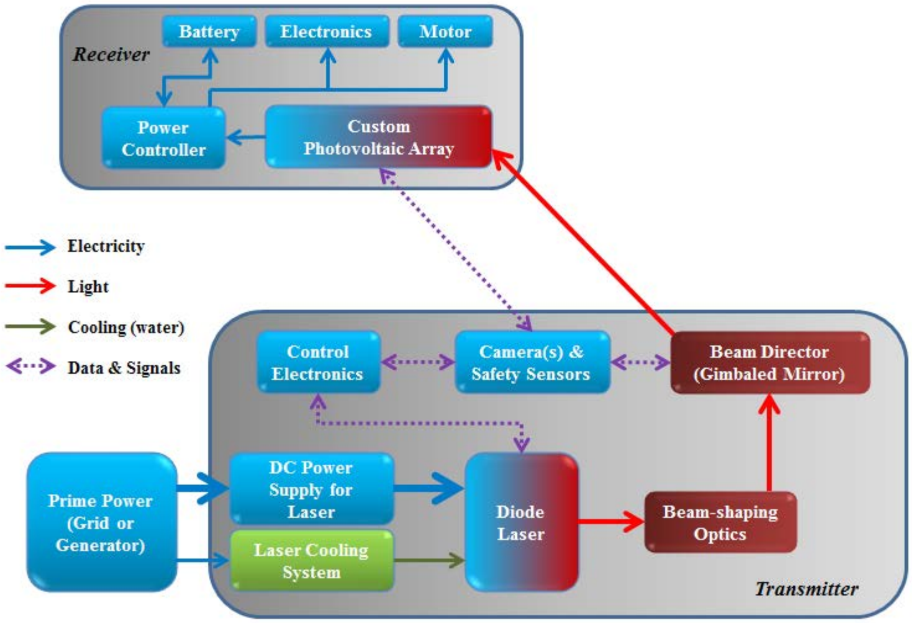

Figure 11: LaserMotive's Wireless Extension Cord[40]

Academia and research labs continue to explore and develop new efficient power methods to increase persistence. For example, utilizing ground-based lasers makes it possible to extend a conventional electric UA flight duration by 2,400-percent. In 2012, Lockheed Martin teamed with LaserMotive to demonstrate this technology by extending the flight time of its Stalker UA from 2 to 48 hours (see Figure 11). In a related test, the Stalker's battery had more energy at the end of the flight than it did at the beginning[41]. The Air Force should continue to partner with National Aeronautics and Space Administration (NASA) and DARPA programs, which are uniquely seeking to enhance persistence and fuel efficiency in SUAS applications (e.g., NASA Environmentally Responsible Aviation Program, DARPA Falcon Project).

4.10. Payloads

SUAS Payloads are comprised of sensors, weapons, and consumables (i.e. fuel pods), and industry continues to reduce SWaP requirements at a rapid rate. Many capabilities once reserved for large aircraft or wing pods can now fit within the constraints of smaller platforms allowing more complex integration.

39 "United States Air Force RPA Vector: Vision and Enabling Concepts 2013-2038." 17 February 2014. 86-7.

40 "How It Works: Laser Beaming Recharges UAV in Flight." 28 July 2012. http://www.popularmechanics.com/technology/aviation/news/how-it-works-laser-beaming-recharges-uav-in-flight-11091133.

41 "Lockheed Uses Ground-Based Laser to Recharge Drone Mid-Flight." 12 July 2012. http://www.wired.co.uk/news/archive/2012-07/12/lockheed-lasers.

4.10.1. Sensors

Sensors are as varied as the spectrum of operations. Today's SUAS sensor technology focus consists of increasing capability through miniaturization which reduces SWaP-C requirements. A prioritized sensor roadmap would focus service and industry labs' research and development efforts on the most needed technologies to meet current and future gaps. For example, a sense-and-avoid and an identification and deconfliction payload will become a requirement on future platforms to facilitate access to the NAS as well as verification of intent during combat operations, respectively. The aperture is just opening on a multitude of sensors, but a detailed discussion of all the various types is beyond the scope of this document; however, a general list of the various intelligence community disciplines is outlined in Figure 12.

Measurement And Signature Intelligence (MASINT) Sub-Discipline & MASINT Technique:	Geospatial Intelligence (GEOINT) Sub-Discipline & GEOINT Technique:	Signals Intelligence (SIGNINT) Sub-Discipline & SIGINT Technique:
Sub-Discipline *Technique* **Electro-Optical** *Infrared* *Laser* *Radiometric* *Spectral* **Geophysical** *Accoustic* *Electric* *Gravity* *Infrasonic* *Magnetic* *Seismic* **Materials** *Biological* *Chemical* *Explosive* *Nuclear* *Radiological* **Nuclear Radiation** *Gamma-rays* *Neutrons* *X-rays* **Radar** *Bistatic* *Line of sight* *Over the Horizon* **Radio Frequency** *Directed Energy Weapon* *Electromagnetic Pulse* *Unintentional Radiated Emission* **Biometrics** ***Placeholder for future NATO work***	**Sub-Discipline** *Technique* **Imagery Intelligence (IMINT)** *Raw Imagery* (Processing and Exploiting) **Overhead Persistent Infrared (IR)** Visible Short-wave IR (SWIR) Mid-wave IR (MWIR) - Long-Wave IR (LWIR) **Full-Spectrum** *Spectral* - Multispectral - Hyperspectral - Ultraspectral *Spatial* - Moving Target Indicator (MTI) / Ground Moving Target Indicator (GMTI) *Temporal* (Time-Varying) *Radiometric* (Radiance / Temperature) - Thermal IR (TIR) - Short-Wave IR (SWIR) - Mid-Wave IR (MWIR) - Long-Wave IR (LWIR) *Phase History Data (PHD)* (from Synthetic Aperture Radar [SAR] Includes: - Coherent Change Detection (CCD) - 2/3/4 Color Multiview - Dynamic Imaging - Vibometry - Polarization Categorization (POLCAT)	**Sub-Discipline** *Technique* **Communications Intelligence (COMINT)** *Traffic Analysis* - Communications patterns & protocol *PROFORMA* - Formatted Data Communications **Foreign Instrumentation Signals Intelligence (FISINT)** *Electromagnetic Emissions* - Telemetry - Beaconry - Electronic Interrogators - Video Data Links **Electronic Intelligence (ELINT)** Includes: - Technical ELINT (TECHELINT) - Operational ELINT (OPELINT) *Radar* *Electronic Attack*

Figure 12: Intelligence Community Disciplines

4.10.2. Weaponry

The increased use of unmanned systems as weapons-delivery platforms has proven to be a monumental shift in the American way of war. When compared to manned airborne platforms, unmanned systems come in a much wider range of classes and sizes, can be used in significantly different operating environments and threat conditions, and exhibit greater persistence and endurance.

The introduction of remote video terminals (RVTs) allows ground operators to view the unmanned system's sensor payload in real time. This further enables users to employ weaponized unmanned systems with more flexibility and confidence. Network accessible SUAS carrying distributed C2 elements, ISR payloads, and weapons are a force multiplier on the battlefield with redundant, self-healing capabilities that greatly complicate enemy decision making.

New weapons technology now enables SUAS to place precision effects on targets. As recent as 2012, Lockheed Martin reported successful kinetic engagement of a vehicle target from a Group 3 Shadow 200 Tactical UAS using a Shadow Hawk precision-guided weapon. Shown in Figure 14, Shadow Hawk is an 11-pound, drop-glide munition with a semi-active laser for terminal guidance[42].

Figure 13: Lockheed Martin Shadow Hawk Munition on a Shadow-200

Another munition considered for Group 3 platforms is the Spike, a forward-firing, miniaturized missile developed by the Naval Air Warfare Center Weapons Division (NAWCWD). The missile performed its first series of controlled flights in 2005 and is designed to be used on medium and light-weight SUAS. NAWCWD is planning to expand their weapon miniaturization program for Group 2 platforms with the new Scan Eagle Guided Munition (SEGM) and the Miniature GPS-Guided Munition (G2M)[43].

42 "Lockheed Martin Develops a Lightweight Precision Weapon for Tactical UAVs." 1 May 2012. http://defense-update.com/20120501_shadow-hawk_uav_weapon_lockheed_martin.html

43 "Arming the Shadows." December 2010. http://defense-update.com/features/2010/december/ 31122010_arming_shadows_4.html

Due to physics, even miniature munitions like the Spike may be too large for some SUAS. In this area, the concept of disaggregated munitions provides growth opportunity for kinetic effects from even the smallest UAS. Teaming a Group 1 SUAS like AeroVironment's Puma AE (RQ-20A) with a pneumatic ground- or air-launched, precision-guided, low-collateral, direct-support UAS munition (e.g. Switchblade--payload and launcher weigh less than 6 pounds) gives operators an organic ability to provide Close Air Support (CAS).

Manned and unmanned teaming is critical to improving the sensor-to-shooter equation and further expediting the kill chain by adapting proven weapons technology with new concepts in persistence and net-centricity. However, certain technological limitations must be addressed to further enhance SUAS as weapons- delivery platforms in the near, mid, and long term[44].

4.11. Human-Machine Interface (HMI)

Advancements in HMI will determine how future operators interact with SUAS. Currently, the U.S. Air Force Academy SUAS program has demonstrated a single operator's ability to employ a maximum of three SUAS safely without an increased workload on the human operator with AFRL/RQ and AFRL/RH studying the workload of operators supervising teams of 12+ autonomous assets. To preclude increased workloads, new developments in HMI are needed to maximize efficiency, minimize sources of error, and allow the human-in-the-loop to focus on the primary mission through goal-based SUAS tasking. Creative concepts and quantum applications in human-machine integration should improve the design of and pilot's interaction with the GCS, mitigation for human error, and air traffic control communications[45]. Flight and payload information should increase levels of autonomy with well-designed HMI elements to enable these advancements.

4.12. Size, Weight, and Power – Cooling (SWaP-C)

DoD wants to reduce the size, weight, and power requirements of military platforms because large SWaP-C impedes mobility and raises maneuvering costs. Day-to-day operations require tradeoffs in available time-on-station when a payload must be added at the expense of fuel quantity. If the payload is too large to add internally, it will be added externally with a corresponding degradation to range/endurance thereby reducing time-on-station. Additionally, UAS programs are limited by the power consumption of payloads. These programs must balance upgrading to larger, more powerful generators, with added weight, space, and cooling concerns.

Miniaturization of aircraft components and payloads generally enables development of smaller, less expensive systems. Miniaturization also typically reduces weight and power consumption. As a result, SWaP-C issues can best be addressed by focusing on compact sensor capabilities. Under DARPA's Precision Inertial Navigation System (PINS)/High Dynamic Range Atom (HiDRA) programs, a "six-degrees-of-freedom" (6DoF) cold atom inertial measurement unit (IMU) is being developed. The 6DoF IMU is a miniaturized three-axis, gyro-accelerometer device that reduces size, weight, and power consumption while still providing precision navigation. Addi-

44 Department of Defense. "Unmanned Systems Integrated Roadmap: FY2013-2038." Reference Number: 14-S-0553. 73-5.

45 Joint Planning and Development Office. "NextGen UAS, Research, Development and Demonstration Roadmap." 15 March 2012. 15.

tionally, miniaturized modular plug-and-play upgrades can be rapidly integrated into existing open architecture systems that employ common standards. DoD envisions reducing stovepipe development and shifting toward standardized architectures to further enable interoperability and reduce costs. Modularity will play a key role in future development efforts to enable interoperability, rapid system upgrades, and synergize DOTMLPF-P. Miniaturized modular systems inherently engender multirole, multi-mission capabilities and further reduce costs by minimizing the integration complexity of new payloads. Ultimately, miniaturization and modularity advancements will permit SUAS to dip into Air Force roles and missions traditionally reserved for larger, more expensive platforms at a fraction of the cost.[46].

4.13. Speed, Range, and Persistence (SRaP)

Today, bound by line of sight restrictions, SUAS are primarily limited by speed, range, and persistence technology gaps. Each, in combination or individually, significantly limits the ability of SUAS to consistently fulfill traditional Air Force missions. Speed is a function of weight and power and today's Group 1 UAS lack the weight and power to overcome high wind environments. Increases in speed are certainly achievable using current technology such as fixed-speed, variable-pitch propellers. Range too, is a function of the size of the SUAS and its capacity to hold the necessary fuel (solar, battery, gas, etc.) to operate over long distances. Increased persistence allows for longer loiter times which negates frequent launch and recovery cycles that limits continuous ISR availability. The Air Force should prioritize SRaP advancements to expand SUAS roles and missions. Priorities should be placed on power plants, beyond line of sight control, and all weather operations.

4.13.1. Air Launched SUAS (AL-SUAS)

AL-SUAS can increase range and persistence providing off-board sensing for manned and unmanned airborne platforms at the right time and place. These SUAS can be controlled from the host aircraft or surface teams trained to operate and employ them. The AL capability enables enhanced flexibility to theater-level assets to conduct ISR, lethal, recoverable, and/or attritable missions. Joint doctrinal shifts may be required to address new and diverse means of AL-SUAS employment. Past lessons learned demonstrate that AL-SUAS are the catalyst to more effective MUM defensive counter air, SEAD, and special operations missions[47]. Furthermore, the evolution of autonomy will enable other users to direct AL-SUAS missions through common tactical data links and maintain precise relative positioning for electronic attack (EA) and SEAD.

46 Department of Defense. "Unmanned Systems Integrated Roadmap: FY2013-2038." Reference Number: 14-S-0553. 61-2.

47 "United States Air Force RPA Vector: Vision and Enabling Concepts 2013-2038." 17 February 2014. 44.

Figure 14: Notional AL-SUAS Off-board Sensing (ALOBS)

AL-SUAS can increase the ISR effectiveness of manned and remotely piloted aircraft by extending the range of host-platforms' capability via off-board sensors. These off-board sensors can provide ISR at stand-off ranges, go below the weather, and/or follow multiple diverging targets (see Figure 15). In addition, SUAS inherent low radar cross section (RCS) characteristics could be leveraged for penetration and sustained operations in contested and denied operating areas.

AL-SUAS can also extend lethal strike capability of manned and remotely piloted aircraft with precision and low collateral damage. This capability was demonstrated by the ground-launched Anubis prototype and is now operational with AeroVironment's Switchblade. Additionally, AL-SUAS provide flexibility not found in current precision weapons with their unique ability to loiter, engage, wave off, and re-engage.

Finally, AL-SUAS provide increased resilience to ground teams. When working with a "stack" of aircraft, AL-SUAS can be launched and "shared" with different users for organic ISR or strike missions. This concept could reduce the weight that a ground user must carry. The expendable or optionally recoverable nature of AL-SUAS does not add unnecessary complexity to missions.

AL-SUAS CONOPS development and system design must complement one another to reduce the impact on a heavily tasked operator. Multiple SUAS in the airspace supervised by a single operator or multiple operators is technically and procedurally challenging. This further complicates airspace control and air battle management for those who are responsible for coordinating and integrating dynamic maneuvers and attacks. The challenges of controlling multiple SUAS simultaneously are being tackled by several cooperative development programs, but further study of C2 systems, processes, and organizations are required to successfully operationalize this vital capability. Adaptable levels of autonomous operations offer a potential solution to these challenges.

Though AL-SUAS currently fill capability gaps of limited niche users, others may gain from this technology advancement. Table 2 illustrates a notional CONOPS of AL-SUAS in support of AC-130 operations.

Mission Area	Description	Anticipated Capability & Benefit	Core Function Lead
Close Air Support	Air Action against hostile TGTs in close proximity to friendly forces	Allows multiple target tracking - multiple team support	ACC/AFSOC
CAS-Troops in Contact (TIC)	CAS w/ friendly forces w/in one kilometer of enemy	BDA - identification of friendly forces	ACC/AFSOC
On-call CAS	Provide fire support to ground party w/out need to loiter overhead	True off-board sensing UAS in area while strike aircraft is outside detection range	ACC/AFSOC
CAS Convoy Escort	Escorts for surface vehicles, maritime vessels or helicopters	Multiple target tracking, monitoring avenues of escape/ingress/egress alternate routes	ACC/AFGSC
CAS Urban Operations	CAS supporting operations in military operations in urban terrain (MOUT)	Minimizing obscuration of targets through urban canyons, minimizing exposure of manned aircraft over urban targets, and multiple target tracking	ACC/AFSOC
Air Interdiction	Air operations to destroy, neutralize or delay enemy military potential before they can be employed	Pre-post interdiction reconnaissance and situational awareness	ACC
Force Protection	Protection of airbase defense and facilities defense	Persistence over small forces while minimizing footprint, exposure of manned aircraft, enhancing situational awareness for forces	ACC
Force Protection - Air Base Defense (ABD)	Direct defense of an airfield and base from hostile forces	Persistence over airbase and tracking potential avenues of approach/retreat, enhancing situational awareness	ACC
Force Protection - Facilities Defense	Defense of friendly forces from hostile forces not necessarily centered around an airfield	Persistence over facilities and tracking potential avenues of approach/retreat, enhancing situational awareness	ACC/AFGSC
Strike Coordination and Recce (SCAR)	Ability to direct air strikes	Aiding in situational awareness, reconnaissance over target area, indentification of friend/foe	ACC
Search and Rescue (SAR)	Ability to conduct search and rescue to locate surface forces or downed aircraft	Can conduct multiple searches in multiple areas simultaneously	ACC/AFSOC

Table 2: Potential Mission Benefits Provided by AL-SUAS

4.14. Materials

Many U.S. weapons system components, such as rocket motors and aircraft wings use carbon fiber technology. The carbon fiber used by current systems was developed in the late 1980s with technology that has reached a plateau. The goal of the Advanced Structural Fiber (ASF) program is to produce a fiber with at least a 50 percent increase in strength and stiffness. ASF focuses on exploiting recent breakthroughs in material synthesis at the atomic level, new material characterization techniques, and advanced manufacturing processes to scale up fiber production technologies that have already shown revolutionary results[48]. Additionally, DARPA continues research in the field of materials with a controlled microstructural architecture (MCMA) that would enable the development of new materials with breakthrough properties. These new materials operate outside the paradigm of currently established property relationships, like materials with the strength of steel but the density of plastic[49]. These new materials will facilitate increased resilience of SUAS. In addition, the technology will advance power plant and other subcomponent capability through lighter weights and increased reliability.

48 DARPA. "Advanced Structural Fiber (ASF)." http://www.darpa.mil/Our_Work/DSO/Programs/Advanced_Structural_Fiber_(ASF).aspx

49 DARPA. "David and Goliath Engineered Into One: Microstructural Improvements Enhance Material Properties." 13 September 2012. http://www.darpa.mil/NewsEvents/Releases/2012/09/13.aspx

4.15. Connectivity

One of the limitations of SUAS is its inability to provide data into the larger COP. This precludes information sharing as well as effective and efficient utilization of systems to meet the larger strategic purpose. For example, the DoD has fielded over 10,000 remote video terminals (RVTs), also referred to as remotely-operated video enhanced receivers (ROVERs). ROVERs are used daily by ground forces and operators to receive FMV feeds from manned/unmanned aircraft, and have been effective in more than 1,000 kinetic employments. Additional capabilities continue to be added to future generations of ROVER as new technologies become available. In the future, these technologies will allow ground forces to provide enhanced targeting information back to SUAS via the NextGen RVT. Expanding reach back capability through extended RVT operations, and new line-of-sight and beyond line-of-sight communication architectures can enhance the COP as well as facilitate battle space employment and information sharing.

4.16. Processing, Exploitation, and Dissemination (PED)

The Air Force's ability to collect information greatly outpaces its ability to use it. Proliferation of SUAS and sensors highlights the need for advanced PED capabilities. Each sensor must accommodate the PED architecture to ensure pertinent intelligence reaches the appropriate organization through the correct channel(s) in a timely manner. Onboard target recognition could be useful for prioritizing imagery for analysis while reducing both the required bandwidth and analyst workload. However, given the immaturity, unreliability, and computational complexity of automatic target recognition (ATR) algorithms, future SUAS programs should be cognizant of the state of such technology and not overly constrain systems to bring ATR into the critical path. Automated subscription services, such as the Integrated Broadcast Service (IBS), could be employed on SUAS to ensure proper distribution to all interested personnel for action. Net-centric operations will make distribution easier, faster, and wider in scope.

The Air Force must ensure that future SUAS advancements are formatted to be interoperable with organic, multi-service, and joint systems to enable the rapid and efficient exchange of relevant information from multiple participants. Because SUAS collect tremendous amounts of data, it must be managed by a regularly updated data disposition policy commensurate with limited bandwidth availability. Increased data compression, onboard processing, and state-of-the-art communications waveforms will reduce bandwidth demand. Burst or event-driven transmissions will also provide relief to communications systems operating at maximum capacity. Improved collection and automated image processing will eliminate irrelevant data before transmission, further reducing bandwidth requirements.

4.16.1. Lack of Streaming

SUAS-Os are unable to transmit intelligence real-time to other entities or commands outside the immediate vicinity of operations. SUAS require LOS link with the air vehicle to acquire the sensor feed, basically limiting observation strictly to the operator or to any user with LOS and a remote video terminal. Larger systems have the capability of transmitting their feed via satellite to multiple locations at any given time, allowing many users the ability to view the feed and make inputs to the decision making process. While RPAs and manned ISR platforms developed methods to pass segments of data electronically to other users, the requirement to develop a SUAS streaming capability connection to operations centers and the AF Distributed Common Ground System (DCGS) PED architecture should be a priority moving forward.

4.16.2. Onboard Processing

Onboard processing is another significant limitation of SUAS. Due to a lack of SWaP-C, many current SUAS payloads do not currently have the capability to process and compress collected intelligence data. For these payloads, Ground-based systems must do the work after mission completion. This may require greater bandwidth requirements at the ground station, as well as increased SUAS-O workload. Improved technologies may enable onboard processing in future SUAS systems making it possible to employ a wider variety of payloads and reduce operator workload.

4.16.3. Data Fusion

The lack of SUAS data fusion with the larger intelligence network is a critical gap. Generally, the SUAS ground station can receive and record real-time mission data, but has no capability to receive or transmit outside its localized, closed-loop system. Enabling an ability to feed raw or processed SUAS data into theater intelligence centers in near-real time without dedicated crews will greatly enhance the theater intelligence picture, supporting planning through operations. Further, enabling SUAS data fusion with other theater intelligence systems will help fill collection gaps thereby increasing the value of SUAS to commanders at all levels. From the Air Force Strategy: A Call to the Future (pp. 15-6), "The fusion, integration, and display of data will be the true force multiplier in the ISR arena, and we must commit to the pursuit of an adaptive paradigm of human-system integration to reach its full potential." With the potential for larger numbers of SUAS, opportunities for integrated intelligence fusion will increase with corresponding efforts to feed SUAS data into the larger intelligence enterprise.

5. Operating Environment

Future operating environments will be as broad and challenging as any the Air Force has ever experienced. Operations will be executed "anywhere in the world, in all domains, and operating conditions[50]." SUAS bring a significant advantage to our Global Integrated ISR and Global Strike core mission capabilities to support our allies and deter or defeat our adversaries in those future complex operating environments.

5.1. Expeditionary

According to Joint Publication 3-0, Joint Operations, an expeditionary force is "an armed force organized to achieve a specific objective in a foreign country[51]." The Air Force further defines the Air and Space Expeditionary Force (AEF) as "tailored and rapidly employable air and space assets that provide the National Command Authority, Joint Force Commander (JFC), and the Combatant Commanders with desired outcomes for a spectrum of missions ranging from humanitarian relief to joint or combined combat operations[52]." As such, the Air Force needs to plan for a balanced force that can be called upon to form Air Expeditionary Task Forces (AETFs) capable of meeting the demands of a wide range of missions. To do this, the Air Force will need sufficient combat-ready capabilities to handle a major theater war (MTW) and other combat operations

50 USAF Strategic Master Plan, January 2015

51 Joint Publication 3-0, Joint Operations, 11 August 2011

52 USAF Scientific Advisory Board, "Report on United States Air Force Expeditionary Forces." Volume 2: Appendices E-H. February 1998.

at short notice as well as enabling capabilities for other (i.e. noncombat) missions to ensure success.

Referencing expeditionary roles in the National Military Strategy, the best approach to determine the appropriate asset mix is to examine a matrix of time/impact/cost outcomes populated by Air Force operational mission vignettes that address distinct Air Force missions as they relate to Air Force Core functions. There are several emerging operational and employment concepts where SUAS augmentation or replacement of existing systems would more efficiently increase combat effectiveness.

5.2. Concepts of Operations (CONOPS)

Much of today's SUAS capability is limited to technologies and connectivity optimized to support niche tactical missions. A CONOPS describes how a force might employ capabilities necessary to meet current and future military challenges. It also obtains stakeholder agreement on functional responsibilities, lines of communication, command and control, and system operation and employment. Advancements in SWaP-C and SRaP will enable SUAS to expand or augment current and future CONOPS. With the relative low cost and increasing functionality of SUAS, the employment of groups of multiple coordinated and interconnected platforms offer improved combat effectiveness and efficiency.

In an ISR collection scenario, collections can be dynamically allocated between groups of task-organized SUAS, assigning the most suitable sensor to each user and target. Multiple sensors can also be massed to focus on a single high-priority target thereby enabling near real-time collection and fusion of multi-INT data from different angles and altitudes. Collectively, SUAS grouping offers resilient persistence through redundant sensors and host platforms that enable better coverage and mission reliability than that of a single platform.

In a weapons employment scenario, the utilization of SUAS in mesh-networks enables intelligent munitions delivery. In this environment, each SUAS provides imagery, such as full motion video and/or LiDAR, for surveillance and targeting. Post-strike SUAS provide near real-time Battle Damage Assessment (BDA) with relevant C2 information transmitted to forward command and control centers. Both weaponized and ISR SUAS can operate over open terrain, using natural surroundings or congested urban areas for concealment. In the future, SUAS will be optimized as Total Urban Dominance Layered Systems (TUDLS) integrating a variety of platforms and payloads at various altitudes to deny enemy operations in all environments[53].

Within this concept, a force of smaller, more agile SUAS will enable the Air Force to mobilize quickly to deter and defeat aggression through power projection despite A2AD challenges. A sufficiently advanced CONOPS could provide the following key capabilities[54]:

- **Vigilance**: Defeat explosive surface, sub-surface (tunnel), and sea hazards from greater standoff distances
- **Flexibility**: Assure mobility to support multiple points of entry

53 http://defense-update.com/features/du-1-07/armedUAVs_9.htm

54 Department of Defense, "Unmanned Systems Integrated Roadmap: FY2013-2038." Reference Number: 14-S-0553. 19.

- **Resilience**: Enable movement and maneuver for projecting offensive operations

- **Networking**: Establish and sustain the lines of communications required to follow forces and logistics

- **Proliferation**: Protect austere combat outposts

- **Persistence**: Provide persistent surveillance to detect and neutralize threats and hazards within single-to-triple canopy and urban terrain

- **Mass**: Enable the effects of overwhelming combat power at the decisive place and time.

The following CONOPS vignettes illustrate new ways of employing SUAS to accomplish tactical to strategic level mission objectives. These vignettes represent only a few of the many SUAS employment concepts for the future Air Force. SUAS have the potential to augment or even redefine airpower employment with game-changing concepts such as swarming, teaming, and loyal wingman (see Figure 15).

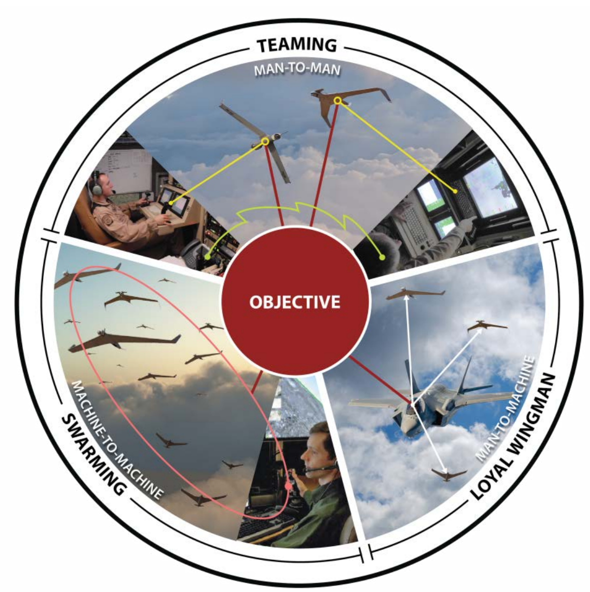

Figure 15: Swarming, Teaming, and Loyal Wingman Comparison

5.2.1. Swarming

The concept of swarming is described as a group of autonomous networked SUAS operating collaboratively to achieve common objectives with an operator on or in the loop. Such concepts employ two or more sensor platforms to accomplish complex mission tasks, exploiting advantages such as the ability to triangulate targets when seen from three or more vantage points. The swarm network will enable the SUAS operator to monitor health and status of the individual assets or the system as a whole. A wireless, Internet Protocol (IP)-based network or other type of communication architecture will connect the SUAS to one another. The network is the key component that enables the swarm to operate as a single cohesive unit while permitting individual platform assignments and simultaneous sharing of real-time data. The networked swarm remains universally aware of its surroundings by sharing both external payload data inputs as well as internal aircraft systems information. This awareness enables the swarm to rapidly process and assign payload requests from authorized users and detect both internal (aircraft system failures) and external (enemy engagement) threats through the use of programmed mission algorithms and sensory information. The SUAS network also permits the swarm to de-conflict and assign the best equipped and operational SUAS for each prioritized task based on location, mission parameters, payload characteristics, and intended effects. Figures 16 and 17 illustrate swarm CONOPS in permissive and A2AD environments, respectively.

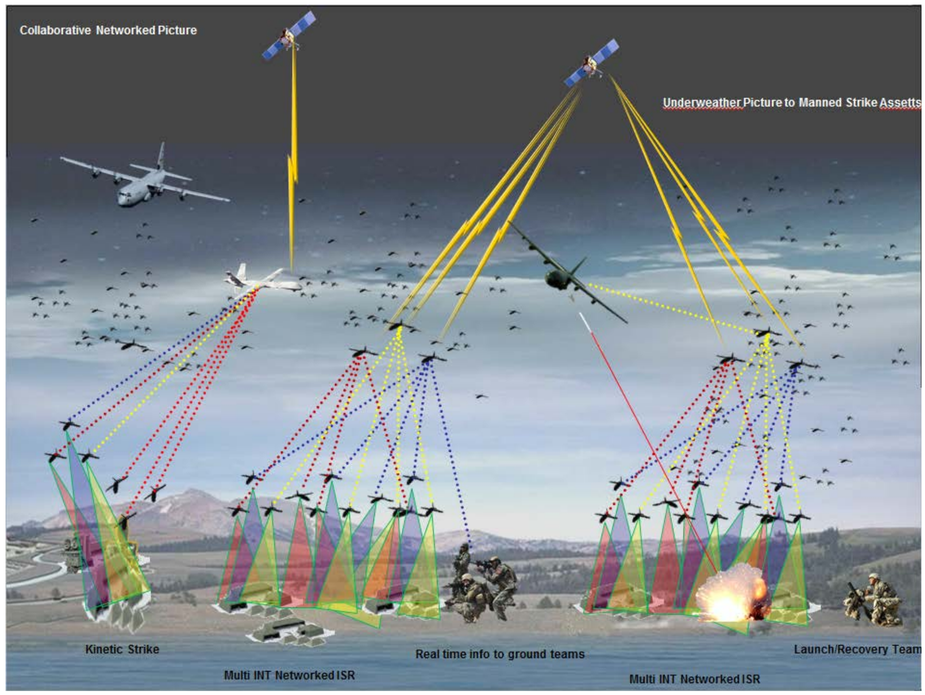

Figure 16: Swarming CONOPS (Permissive)

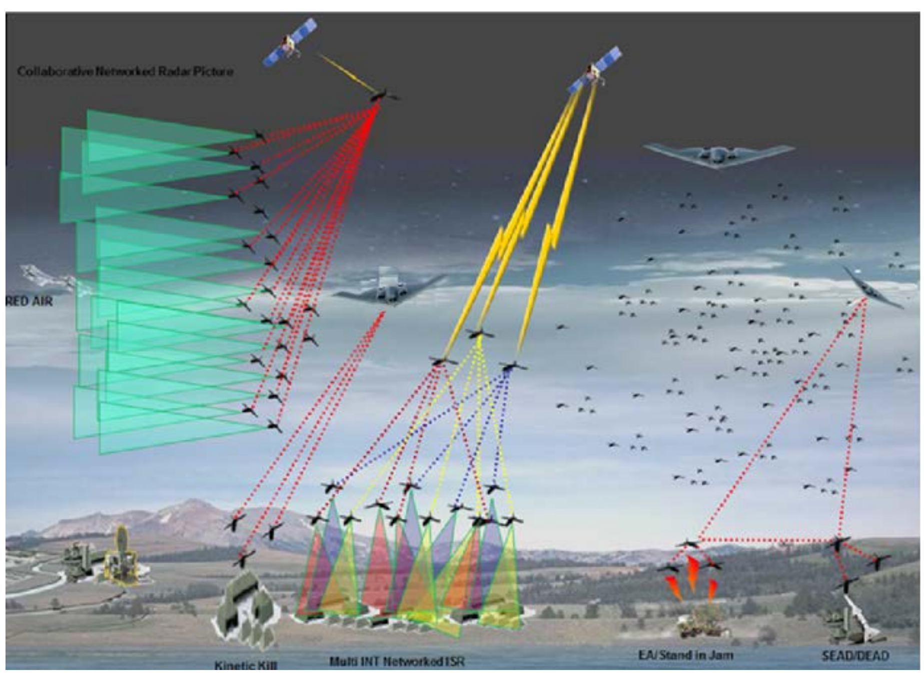

Figure 17: Swarming CONOPS (A2AD)

5.2.2. Teaming

Unlike a swarm, SUAS may be teamed with either manned or unmanned systems retaining some level of in-the-loop control. The collaboration is accomplished at the operator level thereby enabling dissimilar assets to achieve a common objective. Current technology enables integration of unmanned systems with existing RPA, manned, and cyber systems – a true cross-domain warfighting capability. Teaming includes command and control of the SUAS and/or the associated onboard sensors by the remotely piloted or manned aircraft crew, with the ability to actively transfer control to other entities, like a Joint Tactical Air Controller (JTAC). The 2013 DoD Unmanned Systems Roadmap referred to this concept as "Manned-Unmanned System Teaming (MUM-T)"; however, new developments have altered the Air Force perspective. "Teaming" is now understood to be a subset of integration and therefore a more accurate term to represent variations of participants. Figure 18 illustrates a "teaming" concept.

5.2.3. Loyal Wingman

The loyal wingman CONOP combines the efficiencies of manned flight operations with subordinate SUAS to increase the overall capability of the "flight." The loyal wingman concept goes beyond the operational integration of teaming by implementing control principles that enhance mission effectiveness for the lead aircraft. This may include a lead aircraft controlling weaponized SUAS to expand the overall number of munitions beyond what is possible with a single aircraft. Additionally, stealthy aircraft can avoid revealing their position by tasking loyal wingman SUAS to take on roles and missions with the most risk of detection. Loyal wingman SUAS operating as remote sensors, shooters, or decoys add flexibility and survivability for lead platforms thereby expanding access to and sustained operations in higher risk environments.

In the weapons role, loyal wingmen SUAS provide threat detection and avoidance and lethal strike support to their lead aircraft with real-time precision targeting, low collateral damage effects, and live video/sensor feeds to enhance the kill chain. This capability was successfully demonstrated by the ground-launched Anubis prototype and the air-launched AeroVironment Switchblade. The ability to loiter, engage, wave off, and re-engage while the lead aircraft minimizes detection or counters other threats results in efficient employment of high-value assets minimizing expenditure of munitions against low priority targets.

Loyal wingman SUAS increase the overall ISR capability and capacity of the mission commander. These sensors may provide ISR at stand-off ranges, go below the weather, and/or follow multiple diverging targets. Loyal wingman SUAS also may provide cargo support in areas not accessible to other aircraft. In each of these cases, inherent LPI/LPD characteristics of a low cost Group 1-3 UAS results in an ability to penetrate denied areas, a ground-breaking capability that currently does not exist.

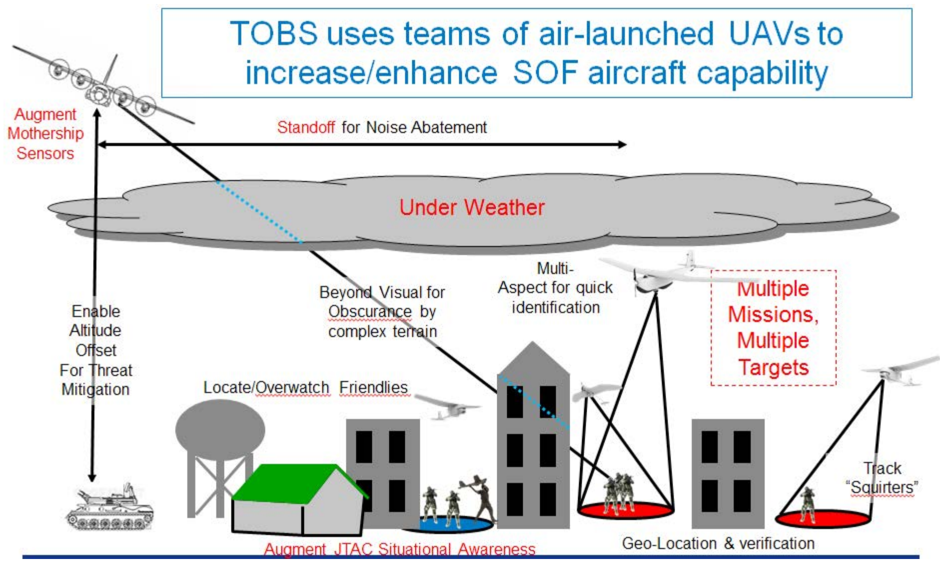

Figure 18: Tactical Off-board Sensing (TOBS) Overview

Finally, loyal wingman provides increased responsiveness to other participants. Figure 19 illustrates a tactical off-board sensing (TOBS) concept for loyal wingmen. The SUAS can be launched and handed off to various participating aircraft for organic ISR or strike missions and can remain in contact with the parent aircraft for target data updates. .

For a loyal wingman CONOPS to be effective, it is essential that the added capability not create an additional burden on the operator. Intuitive HMI and autonomous functionality is needed for multiple SUAS operations. Transfer of control to other users will present training challenges for SUAS crews, especially with control and coordination of multiple aircraft in the same airspace. While similar to the challenges faced by any Flight Lead or Mission Commander, loyal wingmen CONOPS have the potential to further complicate operations if they are difficult to employ. Scalable levels of autonomous operations may mitigate these challenges; and joint force efforts are underway to exercise the full range of current and future capabilities.

5.2.4. Decoys

Due to low costs and more acceptable risk/attrition, SUAS are well-suited to operate in the decoy role. SUAS decoys may actively emit radio, IR, or other signals to deceive an adversary and draw attention away from the primary mission. For example, a swarm of SUAS decoys could conceal a high value asset (HVA) from detection through mimicking a similar radar signature. Using the disaggregated nature of swarms, a portion of the SUAS could provide a decoy target to deceive while the remainder of SUAS disrupt or destroy the target IADS. Decoys should be reusable, but at a low enough cost-point that higher-than-normal rates of attrition make them near-expendable[55].

55 Joint Air Power Competence Centre, "Remotely Piloted Aircraft Systems in Contested Environments." September 2014. 85.

5.3. SUAS Operational Vignettes

The following operational vignettes depict mission sets where future operations can benefit from the employment of Group 1-3 UAS capabilities. These vignettes are not all inclusive; however, they provide relevant illustrations of how these weapons systems can augment and expand future Air Force missions.

5.3.1. Suppression/Destruction of Enemy Air Defense (SEAD/DEAD)

SUAS are ideally suited for the SEAD/DEAD mission. SUAS offer expanded SEAD and DEAD capabilities to disrupt or destroy air defense targets, such as enemy C2 facilities, radar sites, and surface-to-air missile launchers without the threat to pilots. Teaming SUAS with manned or remotely piloted platforms offers flexibility to defeat the adversary's air defense capabilities; AL-SUAS payloads provide mission-tailored packages that detect, jam, neutralize, and/or destroy enemy air defenses; and swarming SUAS saturate and overwhelm enemy IADS or divert attention from HVAs. Lethal or armed SUAS deployed in advance of manned or remotely piloted platforms increase mission success and reduce casualties when confronting a large enemy force. Finally, strategically pre-positioned, lethal, or perching network attack SUAS are used to neutralize air defenses without prior detection. Key SUAS attributes for SEAD include: weapons capability, high subsonic speed, and sufficient range. Sensor performance must enable detection of enemy IADS in all weather and mixed terrain. Multi-ship cooperative control will simplify searching and engagement tasks.

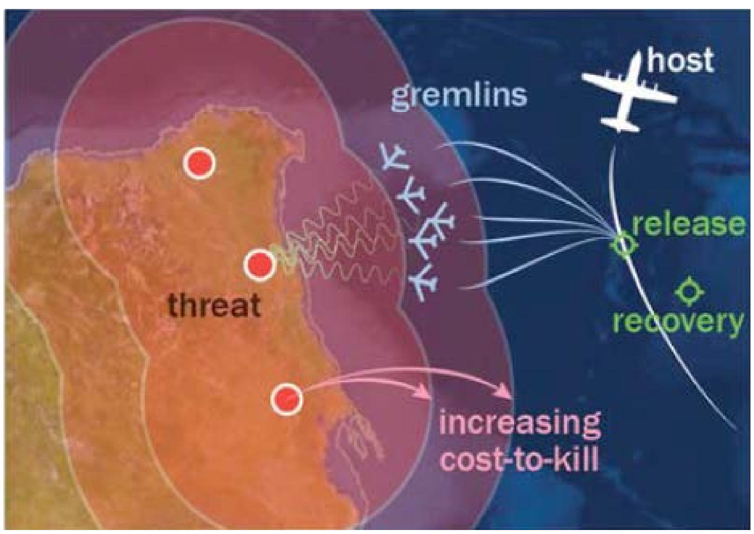

Figure 19: DARPA SEAD/DEAD Overview

One possible scenario envisions a manned or remotely piloted platform positioned outside the threat rings deploying AL-SUAS to penetrate adversary IADS. The stand-off platform provides oversight and management of the SUAS as they conduct SEAD. Figure 20 illustrates a DARPA-developed overview of a notional SUAS SEAD/DEAD scenario. The size and cost of the SUAS make them ideal for this role. In this way, the Air Force can "bend the cost curve" creating economic and tactical challenges for our enemies during sustained combat scenarios (see Figure 21).

5.3.2. Strike Coordination and Reconnaissance (SCAR)

According to Joint Pub 3-03, SCAR is a mission flown for the purpose of detecting targets and coordinating or performing attack or reconnaissance on those targets[56]. SCAR missions are flown in a pre-defined geographic area and provide an interactive C2 function to coordinate air interdiction (AI), detect and attack targets of opportunity, minimize collateral damage, and provide immediate BDA. The geographic area may be defined by a box or grid where potential targets are known or suspected to exist. SUAS are ideal for the SCAR mission allowing the host platform to survive and operate longer in an A2AD environment supporting IADS penetration with a variety of sensor packages. Though traditionally performed by conventional strike and ISR aircraft, SUAS can act as a lead element controlled by both manned and unmanned platforms. SCAR tasks include but are not limited to: locating, verifying, and cross-cueing assets to positively identify moving targets; controlling and sequencing strike aircraft; and passing target updates.

5.3.3. Counter-UAS (C-UAS)

The military use of UAS has increased dramatically over the last decade. In recent years, more than 70 countries have acquired UAS of different classes and for different purposes[57]. The world's inventory of UAS has grown from almost 20 system types and 800 UAs in 1999 to more than 200 systems with approximately 10,000 UAs in 2010[58]. However, while larger category UAS are rather easy to find, fix, and track, the ability to detect and counter SUAS has remained elusive creating vulnerabilities for the U.S. both at home and abroad. While the U.S. has enjoyed information superiority for decades with advanced ISR systems, the low cost and high availability of SUAS enables governments, groups, and even individuals to access real-time information and neutralize this advantage. Most recently, this vulnerability was highlighted on a national stage when an NGA employee crashed a SUAS on the White House lawn without warning. To reverse this trend, the U.S. must prioritize and invest in enemy SUAS counter measures such as advanced jammers and ground and airborne-based radars meant to deceive or destroy the adversary system.

Counter-UAS capabilities are not limited to only ground solutions. The Air Force may find military utility in airborne C-UAS capabilities, to include SUAS, as new technology and operating concepts are developed. International partners and potential adversaries alike are allocating more resources toward SUAS development to confuse and negate expensive, more capable systems. As a result, SUAS may very well represent the new asymmetric threat to the nation.

5.3.4. Beyond-Line-Of-Sight (BLOS)

The inability to operate over the horizon limits the full potential of SUAS. BLOS is a force enabler for emerging persistent SUAS with ranges well beyond C2 link connectivity and difficult terrain settings such as urban canyons where LOS communications are erratic or non-existent. Though limited BLOS applications currently exist for Group 3 SUAS, overcoming this barrier for all SUAS will greatly enhance utility across the ROMO. This limitation will be obviated through continued miniaturization (e.g. antennas), SWaP-C improvements of SAT-

56 Joint Publication 3-03. "Joint Interdiction." 14 October 2011. II-14.

57 The Rand Corporation, "Armed and Dangerous? UAVs and U.S. Security", 1 May 2012.

58 Department of Defense. "Unmanned Systems Integrated Roadmap: FY2013-2038." Reference Number: 14-S-0553. 19.

COM, and emerging alternative PNT and communication technologies. Through the STELLAR BEAM project, OSD-CIO is leading efforts to demonstrate satellite-enabled BLOS for command, control, and communications on the RQ-21A Blackjack, a group 3 platform. While BLOS technology matures, other means exist to achieve SUAS BLOS. Air vehicle relays (AVR) using manned or unmanned platforms utilize existing cell phone architectures or hub-and-spoke/hand-off employment. Continued AVR development is essential to provide a redundant BLOS capability and to counter a SATCOM-denied scenario.

SUAS operations may be enhanced by using several existing communications relay platforms: the Battlefield Airborne Communications Node (BACN) is employed on both the EQ-4 Global Hawk and the E-11A Bombardier Global Express, a specially modified BD-700 aircraft; the Roll-On Beyond-Line-of-Sight Enhancement (ROBE) communications gateway capability is employed on specially modified KC-135 tankers; additionally, some Air Force ISR aircraft have limited airborne relay capabilities. New BLOS TTPs will be required to enable MUM-T or an RPA "mother ship" CONEMP for communications relay.

5.3.5. "Perch and Stare"

AL-SUAS may be the best means to provide persistence at distant, austere locations, especially in A2AD environments. The Air Force should develop technologies to allow SUAS to "perch," collect, analyze, and communicate at very low power levels during long-duration missions (See Figure 21). Perching missions may include ISR collection from cell-phone-sized cameras, micro-acoustic sensors, and small form factor SIGINT packages. New battery technology, solar power, and the ability to use an adversary's power grid require additional research and development[59]. Finally, SUAS have the potential to perform cyber-surveillance and network attacks by perching near network inject points and passing adversary data via localized air and space assets.

Figure 20: Perch and Stare - AeroVironment's Shrike™

5.3.6. Sensor Air Drop

Unattended ground sensor (UGS) systems employ various sensor modalities including seismic, acoustic, magnetic, and pyroelectric transducers, daylight imagers and passive infrared imagers. UGS emplacement serves many different functions including indications and warning, communications relay, weather reports, activity identification, high-value individual

59 "United States Air Force RPA Vector: Vision and Enabling Concepts 2013-2038." 17 February 2014. 43.

detection, kinetic weapon cueing, and near-real-time alarms for predictive force movements providing reports or imagery to PED cells. Unmanned systems enable placement of sensors deep into enemy territory and along supply routes to increase persistence, surveillance activity, and identifying targets without putting lives at risk.

UGS can collect and report unique geolocation information in support of accurate covert emplacements. Future SUAS may be ideal for penetrating denied battlespace to accurately dispense UGS and non-kinetic capabilities, such as "attach bots," that provide critical intelligence value well before adversary C2 and IADS have been denied or defeated[60].

5.3.7. Weather Sensing

The Air Force employs UAS 24/7 around the globe in all areas of operations, at various altitudes, and in constantly changing environments. These missions require accurate and timely weather forecasts for multi-day mission planning, sensor planning and data collection in support of the CCDR, and aircraft safety and mission-limiting mitigation strategies. Accurate weather reporting also supports complementary ground and flight planning synchronization. Today, AFSOC meteorologists use RQ-11B Ravens to collect weather data. In the future, every airborne asset will be a weather "sensor" autonomously collecting and reporting near-real-time data to the DCGS enterprise, AOCs, and CONUS weather data bases. SUAS weather data, collected in real time, will be correlated with other weather information to improve accurate assessments for the tactical commander. Weather sensing information will be automatically formatted and reported via the platform's data link with automated routing to the appropriate weather prediction and reporting stations. As SUAS endurance increases, precise multi-day weather forecasts will become more imperative to ensure all phases of flight contribute to safe and effective mission accomplishment[61].

5.3.8. Airborne Layered Network (ALN)

With incremental improvements in electronic discovery, interface design, and adaptive protocols, self-forming and self-healing mesh networks better enable multi-platform, multi-sensor SUAS networks[62] to support operating concepts such as swarming. ALNs support numerous and diverse sensor data types that create a localized common operational picture for a more holistic situational awareness (See Figure 22).

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60 Department of Defense. "Unmanned Systems Integrated Roadmap: FY2013-2038." Reference Number: 14-S-0553. 29.

61 Department of Defense. "Unmanned Systems Integrated Roadmap: FY2013-2038." Reference Number: 14-S-0553. 30.

62 Department of Defense. "Unmanned Systems Integrated Roadmap: FY2013-2038." Reference Number: 14-S-0553. 52.

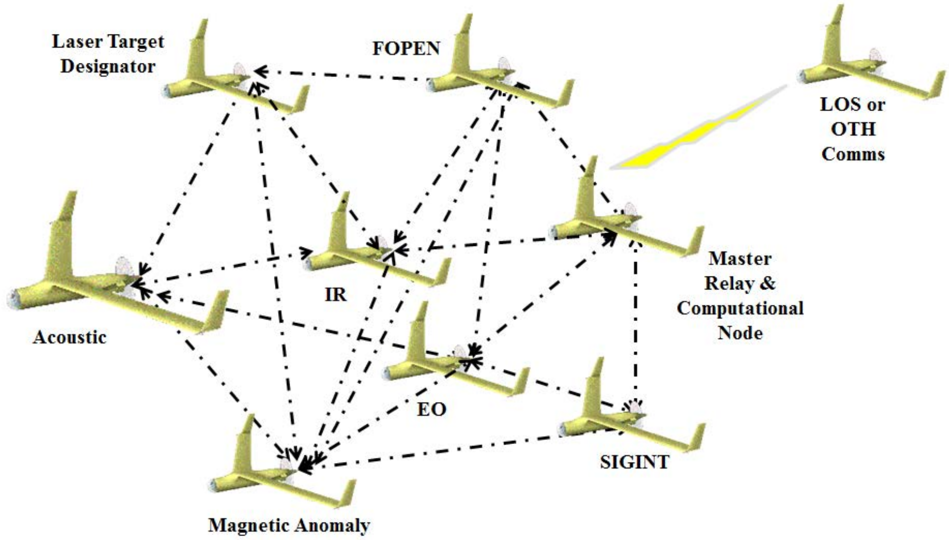

Figure 21: Possible Airborne Layered Network Configuration

An example is Lockheed Martin's Self-Powered Ad-hoc Network (SPAN), a UGS network that provides unobtrusive, continuous surveillance for a variety of missions and applications such as border protection, area surveillance, and monitoring of bridges, pipelines, aircraft, and other structures[63]. Additionally, AFSOC is conducting a limited utility assessment of the Persistent Systems Wave Relay® radio on Stark Aerospace's ArrowLite™ to determine the feasibility of mesh networks in austere environments. This radio weighs fewer than 7 pounds and establishes a mobile ad hoc network (MANET).

Multi-Input Multi-Output (MIMO) communication is another proven technology currently used in commercial fourth generation (4G) wireless systems that can support meshed networking. It uses multiple transmit and receive antennas to multiply capacity and has been tested at data rates up to 300 Mbps. MIMO combines information theory, forward error correction coding, signal processing, and propagation theory. Additionally, MIMO uses multiple paths with lower data rates on each path and applies space-time coding and capacity optimization to support high data rate missions. Finally, this application would apply power savings to jammer margins and evaluate performance in benign and stress conditions.

5.3.9. Nuclear Weapons Enterprise Operations Support

SUAS may also be used to augment myriad security missions, such as a Weapons Storage Area or perimeter security on a main operating base. However, due to the sheer size and remoteness of the Air Force's Intercontinental Ballistic Missile (ICBM) complexes, SUAS are ideally suited to augment security situational awareness during routine and contingency situations. SUAS may also be used to augment security missions that are not located within an ICBM complex, such as a Weapons Storage Area located on a main operating base. Possible missions/uses of SUAS within the ICBM complex include but are not limited to:

63 "Lockheed Martin Links Ground Sensors to Unmanned Aircraft Systems." Lockheed Martin Press Release. http://www.uasvision.com/2013/10/25/lockheed-martin-links-ground-sensors-to-unmanned-aircraft-systems.

- **Security Response Team (SRT).** SRTs generally respond from the Missile Alert facilities (MAF) to geographically dispersed Launch Facilities (LF) when alarms occur at the site. Using SUAS, site Security Forces could conduct more rapid characterization of perimeter alarms and areas surrounding the LFs.

- **Mobile Fire Team (MFT)**. MFTs patrol the ICBM complex in designated areas and loiter where degraded security conditions exist such as open LFs, maintenance-penetrated LFs, or LFs with inoperative alarms. They could employ SUAS for area ISR to provide direct fire onto affected sites (LFs or MAFs).

- **Camper Alert Team (CAT)**. CATs stay overnight at LFs where degraded security conditions exist. In this role, they could employ tethered Vertical Takeoff and Landing (VTOL) SUAS to conduct ISR and indications and warnings around affected LF.

- **Security Escort Team (SET).** SETs are responsible for escorting maintenance personnel to LFs and providing security at the surface of the LF while maintenance personnel complete actions inside the LF. A SET could employ tethered VTOL SUAS to conduct ISR around affected LF.

- **Convoy Response Force (CRF).** CRFs escort warheads to/from ICBM complex via ground transportation accompanied by Airborne Fire Teams (usually TRF—see below). They could employ SUAS to perform route recon and site ISR. An Airborne Fire Team could use Lethal Miniature Aerial Munitions Systems (LMAMSs) to delay enemies on site, counter ground attacks, and disable/destroy fleeing vehicles.

- **Tactical Response Force (TRF)**. TRFs are an in-extremis force specially trained for recapture and recovery of ICBM-deployed nuclear weapons. A TRF could employ SUAS for ISR of affected site during recapture and LMAMs to provide delay and denial of site during target approach. Tethered VTOL SUAS could be used after site recapture while awaiting friendly force relief and LMAMs could be used to help hold the recaptured site if follow-on enemy forces counterattack.

- **Airborne Security Element (ASE)**. ASEs provide day and night patrols of ICBM complexes, focusing on LFs with degraded security conditions and can conduct visual assessment of LF alarm situations. Patrols could be done completely via SUAS and piloted from MAFs, Missile Support Bases, or via swarming air launched SUAS to check multiple penetrated LFs.

- **Backup Force (BF).** BFs respond during emergency situations where additional forces are necessary to augment the on-duty forces. Imagery from SUAS could significantly improve the situational awareness of the BF by providing personnel with real-time information prior to their arrival at the response site.

5.3.10. Information Superiority

With the modern quick-turn information environment, it is all the more important for Combatant Commanders to possess detailed situational awareness from any location in the world. Rapidly transmitted still photos and motion video from a SUAS not only provides commanders with a bird's eye view to make even faster critical decisions, but also at a fraction of the cost and risk of a manned aircraft mission. In wartime environment, FMV recorded from a

SUAS would allow tactical leaders to understand terrain and future movements. During crisis relief operations, a SUAS will provide responders with data on where they can safely travel and who they can assist first.

6. Logistics and Sustainment

6.1. Current Sustainment Environment

The first generation of fielded SUAS prioritized rapid delivery through sole source procurement to meet warfighters' urgent operational needs. Because of the urgency to quickly field initial capabilities, long-term sustainability and interoperability planning occurred late in the development cycle or not at all. Though the family of SUAS has varying degrees of complexity, reliability, and maintainability, logistically speaking, they are no different from manned platforms in that they require investments that ensure availability and sustainment over the life of the system. As programs plan for long-term normalization, program managers must establish cost-effective life-cycle sustainment strategies that meet documented warfighter requirements while complying with DoD policy and regulations.

6.2. Challenges to normalization of Logistics and Sustainment

As the Air Force pursues unmanned efficiencies in an uncertain global environment, the desire for rapid acquisition and fielding continues to challenge logistics and sustainment planning and implementation.

6.2.1. Sustaining Non-PORs

Continuous high operations tempo has prompted numerous JUONs, UONs, and ISR QRCs resourced through OCO funds. Typically, CLS is utilized to enable a quick sustainment option to meet urgent warfighter need timelines. As a result, QRC-procured SUAS are difficult to sustain over a long-term strategy due to reliability, availability, maintainability (RAM) limitations. Additionally, unit-based procurement of multi-copter COTS systems without sustainment complicates Air Force Core Logistics Capability Requirements and organic Military Sustainment. These non-POR systems can increase maintenance costs.

6.2.2. Limited Reliability, Availability, Maintainability (RAM) Data

As with other ISR QRCs, SUAS capabilities were delivered rapidly using CLS, but lacked military standards for system RAM metrics. Life-cycle RAM considerations are typically the single largest design-controlled variable for operations and sustainment costs. While providing an expedient capability to the warfighter, QRCs that transition to PORs typically must keep CLS sustainment in place, at least in the short-term, while an organic capability is developed and integrated. The logistics support concept should be revamped to consider military RAM standards and sustainment of organizational and manpower structures.

6.2.3. Core Logistics Capability Requirements

Just recently, several SUAS QRC programs have begun the transition from CLS sustainment to organic military logistics. Through this process, the Air Force has learned that transitioning to a military depot capability is often complicated by legal assertions of contractor proprietary technical data rights[64], additional investment costs for support equipment and facilities, parts obsolescence, and frequent software upgrades. For UAS, Services typically select a preferred mix of vendor solutions to satisfy requirements for ISR and Global Attack QRCs. While there is a large degree of commonality among the platforms and sensors of each Service, inter-Service commonality remains arbitrary. In an effort to create core military maintenance efficiencies, the Services have initiated efforts to identify synergies for common sustainment concepts and capabilities. According to the Unmanned Systems Integrated Roadmap, the Army conducted a UAS Organic Depot Study and recommended leveraging existing depot capabilities and capacity by establishing repair operations at strategically located depots based on major subsystems.[65] The Joint Logistics Board endorsed this concept and directed that Air Force avionics, ground electronic, software, and sensor workloads be further evaluated for potential consolidation.

6.2.4. Transition from CLS-for-Life to Organic Capabilities

SUAS QRC program managers recognize the life-cycle cost impacts of relying on CLS long-term. As a result, program offices are now establishing common logistics infrastructures to reduce investment costs as they transition to organic military sustainment. CLS, in many cases, is not performance-based, but instead focused on cost-plus-award-fee arrangements providing flexibility to respond to OPSTEMPO-driven changes in requirements.

For Group 1 platforms, the United States Marine Corps (USMC) instituted a logistics capability at their Field Training Unit (FTU). This Training and Logistics Support Activity provides operator training as well as logistics and maintenance support to USMC units. Parts are procured through open-source contracting while support for system upgrades, battery charging, platform training, and general information are accomplished on site at reduced costs with shorter lead time. Additionally, using a consolidated issue facility, the USMC maintains centrally located control of all systems unless required for training or deployment. This has several benefits; first, the consolidation allows for centrally-managed preventive maintenance, accountability, software, and hardware version control. Second, with the ability for units and individuals to "check out" systems only as needed, it reduces the approved acquisition objective. The result is fewer system inventories, less maintenance, reduced costs, improved delivery of system upgrades, and simpler management to demilitarize and dispose of obsolete systems. Since all systems rotate through the CIF, accountability and timely maintenance occur without impacting operations.

6.2.5. Life-cycle Sustainment Planning

Due to the many varied SUAS configurations being fielded, there is a large volume of nonstandard equipment (NSE) requiring support. As the Air Force and other Services transition SUAS to organic sustainment, building modularity into next generation SUAS will reduce part inventories, minimize integration costs, and achieve significant cost avoidance. The optimum goal is to attain modularity across platforms for PnP adaptability. This approach will reduce the number

64 10 USC 2320 provides that in the case of an item developed by a contractor or subcontractor exclusively at private expense, the contractor or subcontractor may restrict the right of the United States to release or disclose technical data to persons outside the Government. The statute further states that these restrictions do not apply to technical data that are necessary for operation, maintenance, installation, or training.

65 Department of Defense, "Unmanned Systems Integrated Roadmap: FY 2013-2038."

of required repair parts and allow PnP payload options to fulfill multiple capability requirements. This effort will also maximize the lifespan of future SUAS and save substantial resources in repairs and spare parts.

6.2.6. Spares

Consider purchasing sufficient system spares to replace units damaged or contaminated by CBRN agents. The Air Force must properly plan for the disposal of damaged or contaminated units to prevent enemy exploitation or cross-contamination of friendly forces.

6.3. The Way Ahead

For SUAS to move from a wartime environment characterized by rapid development and fielding to a more traditional requirements and acquisition approach, life cycle planning and costing must be considered early in the JCIDS requirements process. As new SUAS materiel solutions are considered, decision makers should apply life-cycle analysis to ensure affordable long-term sustainability.

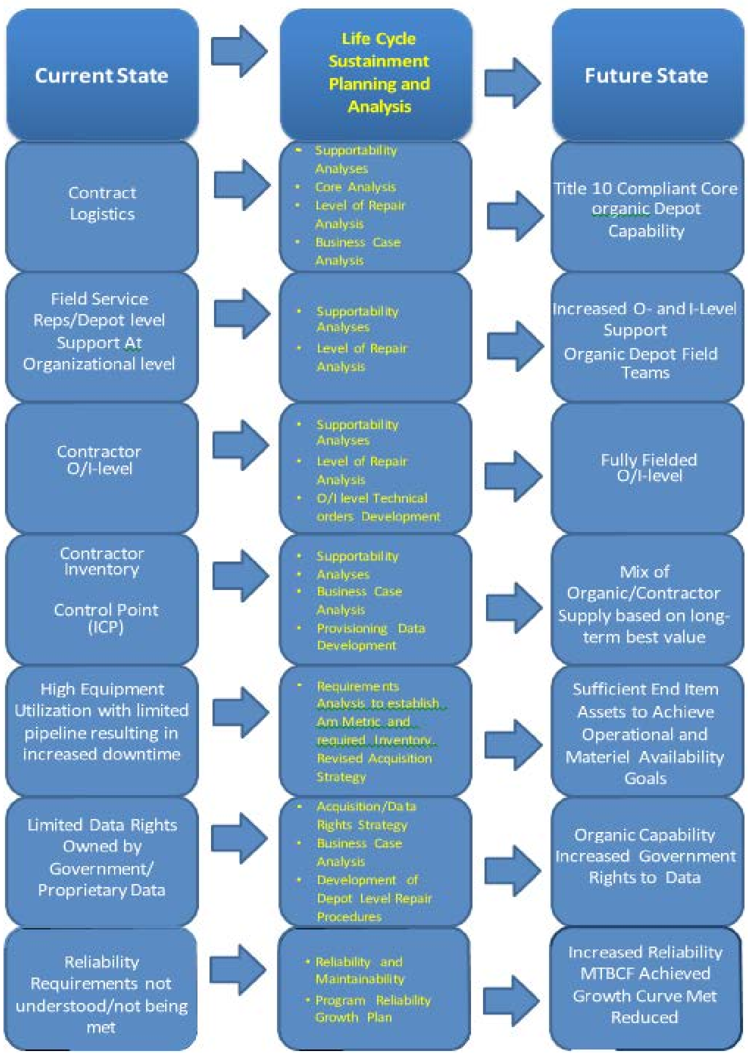

Figure 22: Life-Cycle Sustainment Planning Analysis Way Ahead

In September of 2011, the Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics (OUSD (AT&L)) directed sustainment plan development for all unmanned acquisition programs along with reviews for improved affordability and effectiveness. This renewed emphasis highlighted the importance of life-cycle logistics planning and analysis execution from the acquisition phase, through operations, and into the retirement phase of the weapon system. Cross-functional planning brings together the activities of various functional groups in support of a single program. As such, cross-functional planning and integration are essential to ensure long-term supportability requirements are comprehensively and consistently addressed within life-cycle cost, schedule, and performance decisions. Ultimately, these life-cycle adjustments will enhance operational effectiveness through an affordable, effective support strategy designed to improve readiness and advance new technologies (see Figure 23).

6.4. Planning for Organic Depot Maintenance

Central to sustainment planning and execution is the concept of core depot-level maintenance. The determination that a function is "core" requires that government-owned and government-operated depot-level maintenance and repair capabilities and capacity, including the facilities, equipment, associated logistics capabilities, technical data, and trained personnel, be established no later than four years after a weapon system or item of military equipment achieves Initial Operational Capability (IOC) or is fielded in support of operations. First codified in 1984 U.S. Code (10 U.S.C. 2464), the Fiscal Year (FY) 2012 National Defense Authorization Act (NDAA), as amended in the FY2013 NDAA, introduced several new provisions related to the identification and implementation of core logistics capabilities that affect the sustainment of UAS.

A determination on core logistics applicability is made at three different stages of the acquisition process. First, the Milestone Decision Authority (MDA) must now certify pursuant to 10 U.S.C. 2366a(a)(4), "that a determination of core logistics capabilities requirements has been made," prior to Milestone A approval.[66] Second, Milestone B approval may not be granted until the MDA certifies, "an estimate has been made of the requirements for core depot-level maintenance and repair capabilities…and the associated sustaining workloads to support such requirements."[67] Third, the U.S. Code states, "prior to entering into a contract for low-rate initial production of a major defense acquisition program, the Secretary of Defense shall ensure that the detailed requirements for core logistics depot-level maintenance and repair capabilities… and associated sustaining workloads required to support such requirements have been defined." This 3-stage process is designed to identify organic depot-level maintenance requirements early in the acquisition cycle to reduce the need for interim CLS and to allow for the establishment of organic capabilities.

The early identification of core requirements and sustaining workloads will drive programs to identify and acquire data to establish repair capabilities early in the acquisition process. DoD also must be ready to challenge assertions that unmanned systems were developed exclusively at private expense; or at a minimum, be prepared to aggressively assert its "Government

66 10 USC 2366a. "Major Defense Acquisition Programs: Certification Required Before Milestone A Approval." 2011.

67 10 USC 2366b. "Major Defense Acquisition programs: Certification Required Before Milestone B or Key Decision Point B Approval." 2011. Section (a)(3)(F).

purpose rights" (under the provisions of 10 USC 2320) to the technical data required to maintain these systems.[68]

6.5. Sustainment Metrics and Performance-Based Logistics (PBL)

The 12 February 2015 JCIDS Manual establishes the Sustainment Key Performance Parameter (KPP) as applicable to all CDDs and Capability Production Documents (CPDs). This Sustainment KPP is intended to ensure an adequate quantity of the capability solution will be ready for tasking to support operational missions. The supporting Reliability KSA and Operational and Support (O&S) Cost KSA, ensure that the Sustainment KPP is achievable and affordable in its operational environment. Together, the KPP and supporting KSAs ensure early sustainment planning, enabling the requirements and acquisition communities to provide a capability solution with optimal availability and reliability to the warfighter at an affordable life cycle cost.

Establishing programs to ensure that reliability thresholds are met have great potential to satisfy long-term SUAS affordability and operational availability goals. Incorporating design features to enhance maintainability and supportability will increase readiness and lower O&S costs. Specifically, incorporating modularity and common interfaces and standards will enable integration of new sensors, weapons, and communications without major platform redesign or replacement. Modularity and common interfaces and standards improve maintainability by simplifying fault isolation and subsystem removal and replacement. Additionally, in-flight diagnostic and prognostic technologies accelerate repair turnaround thereby improving readiness. As SUAS portfolios mature, responsible PEOs and program managers now have the tools to create efficiencies with common components and configuration elements such as batteries, fasteners, electrical distribution panels, and support equipment. Commonality creates opportunities for common supply chains, sources of repair, and other product support elements.

The services rely on the private sector to supply goods and services needed to perform government functions unless there is some compelling reason to maintain "organic" capability. The requirements of integration, modularity, flexibility, and the ability to expand rapidly into new capabilities are compelling enough; however, continued reliance on single-source vendors to meet every emerging requirement is creating an inventory of disparate and non-compliant systems with little utility beyond a short service life. While the relatively low costs may justify the expense, organic maintenance will provide greater functionality and serviceability. Continued life cycle support can offer surge capability, a broad scope of repair, and be sensitive to operational force requirements.

7. Training

To produce well-trained operators, sound training requirements are essential for safe, effective SUAS operations. The Air Force must continually refine these training requirements based on data and lessons learned from evolving SUAS doctrine and operations. The diversity in UAS designs, missions, and vehicle technology architectures makes it difficult to prescribe a standard set of universally applicable training certification requirements for the operator. For this reason, SUAS groups/categories are mapped and tailored to an appropriate level of knowledge equivalent to the

68 10 USC 2320. "Rights in Technical Data." 2011.

type and capability of UAS employed. Training ensures the proper knowledge, skills, and attributes are provided to the crew for safe operations.

The lead SUAS-O on a mission is the Pilot in Command (PIC) and must be trained and certified to fly the unmanned aircraft in varying environments. UA may be employed in close proximity to people, structures, surface vehicles, and/or other manned and unmanned aircraft in varying terrain, airspace classifications, and weather conditions. As such, appropriate operation and employment instruction remains critical to effective mission accomplishment. No matter how automated the SUAS operation, a human is still required to perform critical functions. The SUAS-O sets mission tasks, plans airspace integration, communicates with various command and control elements, executes the mission, and adapts to changing conditions. Therefore, flight characteristics, airspace coordination, and mission safety are critical elements required for a SUAS training program. There are three levels of training standards required to maintain flight proficiency: initial qualification training (IQT), mission qualification training (MQT), and continuation training (CT). This section will describe UAS-specific considerations for building an enduring SUAS training program in accordance with governing policies.

7.1. Training Requirements

The primary document governing training is CJCSI 3255.01, Joint Unmanned Aircraft Systems Minimum Training Standards (JUMTS).[69] The CJCSI standardizes the minimum knowledge required for basic and Joint UAS mission qualifications for UAS operators. The instruction satisfies a Joint Requirements Oversight Council (JROC) directive "to prepare aircraft crew members to perform in a joint environment by standardizing training and certification." JUMTS qualification standards meet existing FAA manned aircraft standards and are required for UAS access into the NAS. Additionally, JUMTS reflects findings in the Joint UAS Training Qualifications and Standards Architecture study report[70] which describes a modular, capabilities-based approach to UAS training. It also links UAS training with the Tier 1 JCA and tasks in the current Universal Joint Task List (UJTL).

JUMTS establishes five critical skill sets required to effectively operate and employ UAS, regardless of the operational environment.

7.1.1. Basic UAS Qualification (BUQ)

A BUQ certifies the operator has the minimum general aviation knowledge and UAS knowledge-based skills to operate UAS safely for each crew duty position (i.e. Pilot / Aircraft Operator). BUQ levels build upon one another; for example, BUQ Level I is the prerequisite for BUQ Level II and so forth.

- BUQ Level I is the minimum recommended training level for a UAS operator and those crew members that perform duties other than pilot (e.g. Aircraft Operator/Sensor Operator). Associated SUAS crew members must possess the required aviation knowledge and UAS knowledge-based skills to fly under Visual Flight Rules (VFR) in Class E, G, and restricted/combat airspace <1200′ above ground level (AGL).

69 CJCSI 3255.01. "Joint Unmanned Aircraft Systems Minimum Training Standards with Change 1." 31 October 2011.

70 JUAS COE, USJFCOM Study Report. "Joint UAS Training Qualifications and Standards Architecture." 25 September 2008.

- BUQ Level II requires additional requirements additive to BUQ I and ensures SUAS crew members possess the required aviation knowledge and UAS knowledge-based skills to fly under VFR in Class D, E, G, and restricted/combat airspace <18,000′ mean sea level (MSL).

- BUQ Level III builds upon BUQ II and requires SUAS crew members to possess the required aviation knowledge and UAS knowledge-based skills to fly under VFR in all classes of airspace except U.S. and ICAO Class A.

- BUQ Level IV adds to BUQ III requirements by ensuring crew members possess required aviation knowledge and UAS knowledge-based skills to fly in all weather conditions and classes of airspace up to Flight Level (FL) 600.

7.1.2. UAS Flight Crew Skills

UAS flight crew skills are practical skills including the situational awareness required to safely operate UAS and execute required tasks during flight operations. Flight crew skills satisfy practical flight requirements for BUQ Levels I through IV. The Services and USSOCOM are responsible for identifying UAS flight crew skill requirements. For the Air Force, AFI 11-502 regulates these skills.

7.1.3. Joint Mission Qualification (JMQ)

JMQ provides general knowledge of the UAS mission/objective. JMQ levels are critical to ensure that crews understand their role in accomplishing a larger military objective. The JMQ levels correlate to appropriate joint missions.[71]

- JMQ-A requires qualifications to support unit-level ISR and Fires tasks in support of the JFC. Mission support with capabilities is defined in the Joint Mission Task Lists (JMTL).

- JMQ-B qualifications support theater-level advanced ISR/Incident Awareness and Assessment (ISR/IAA) in support of the JFC's defined capabilities in the JMTL.

- JMQ-C qualifications support strategic-level Fires and Combat Search and Rescue (CSAR)/Personnel Recovery tasks in support of the JFC as defined in the JMTLs.

7.1.4. UAS Mission Crew Skills

UAS Mission Crew Skills are required to ensure assigned task accomplishment. Mission crew skills include the ability to execute joint TTPs to meet UAS employment mission objectives. UAS Mission Crew Skills meet practical mission requirements for JMQ Levels A through C. The Services and/or USSOCOM will determine/specify UAS Mission Crew Skill requirements.

7.1.5. Unique Service Skills

Unique Service skills provide the UAS crew member with the knowledge and understanding of Service specific missions and associated requirements. Examples include pre-strike reconnaissance for air interdiction and maritime environment for naval UAS.

71 CJCSI 3255.01. "Joint Unmanned Aircraft Systems Minimum Training Standards with Change 1." 31 October 2011.

A UAS crew member is considered JUMTS certified if they complete initial qualification training and maintains currency by achieving the minimum recurring training and assessment requirements as designated by their respective organization (Service, USSOCOM). In accordance with CJCSI 3255.01, SUAS operators must meet the following JUMTS requirements for the UAS group they operate.

- Group 1: BUQ I and JMQ A
- Group 2: BUQ II and JMQ A
- Group 3: BUQ II and JMQ B

As systems become more capable, interoperable, interchangeable, and autonomous, training requirements and timelines may lessen, but the standards will be no less important.

7.2. Challenges to Training

With limited access to national and international airspace, there are some challenges to initial and recurring continuation training of SUAS-Os and crew members.

7.2.1. 7.2.1 SUAS Training Resources

UAS training requires airspace and ground facilities sufficient in size to permit effective instruction. UAS operations also require pre-authorized spectrum for UAS C2, sensor control, and downlink of sensor data.

- **Line-of-Sight (LOS).** Some SUAS training is conducted within visual LOS of the control segment. This airspace may be as small as a 1000-meter radius. However, tactical training against realistic stationary and moving targets should be conducted out to the data link(s) radio LOS limits. In some cases, this airspace may be 20 kilometers or more from the control station. When multiple networked UAS are employed, the airspace must be sufficient to optimize each UAS's sensor's search area and provide opportunity to cross-cue additional UAS onto specific targets.
- **Beyond Line-of-Sight (BLOS).** With continued miniaturization of satellite link technology, SUAS BLOS capability is growing and will improve future SUAS training opportunities. Certain Group 3 SUAS currently have INMARSAT near-global BLOS coverage through the use of SATCOM. Training becomes more complex in this environment, but enables operations on a global scale. As a result, UAS operators must be trained on international airspace standards to ensure safe aircraft operations.
- **Airspace.** Groups 2 and 3 SUAS and all sizes of AL-SUAS will require access to larger volumes of airspace to accommodate their performance characteristics and effectively train with their sensors. Both U.S. and host nations will require most training to be conducted in Special Use Airspace until routine access is granted through regulations and standards or through better simulation. However, current FAA policy has increased restriction on all forms of UAS. Current reports point to this problem but significantly understate the challenge of obtaining Special Use Airspace or deregulating standard NAS for UAS from the FAA. The ICAO takes a similar stance and indicates an increase, rather than a decrease, in regulations and limitations.

- **Realism.** Realistic mission-specific training is essential for successful UAS flight and mission crew member training. While IQT requires fixed targets and opportune employment of systems, MQT requires actual or realistic replica targets and emitters in order to provide meaningful training to the student. Moreover, mobile targets require qualified drivers, appropriate vehicles, and associated terrain in order to present the required scenarios and learning objectives. Robust simulation may be used to fulfill a significant number of these advanced training requirements and should be considered early in the acquisition process.

7.2.2. Plan of Instruction (POI)/Syllabus

Each Air Force Mission Design Series (MDS) UAS requires development of a formal POI to meet the standards described in AFMAN 36-2234, *Instructional System Development* and AFMAN 36-2236, *Guidebook for Air Force Instructors*. The Lead Command is responsible for continual assessment of the POI to ensure it meets those standards while supporting current operations.

7.2.3. Instructor Cadre

Trained, certified, and competent instructors are required to teach the approved curriculum. Currently, experienced SUAS-Os are difficult to amass because they are not presently considered a formal career field. Instructor candidates must be trained in both basic SUAS operator qualifications and formal techniques of instruction. Instructor candidates should receive operational training in order to provide student SUAS-Os with comprehensive qualified IQT instructors.

Unit-developed and trained instructors provide MQT, the second half of the training continuum. Unit level SUAS-O instructors are selected from the most capable SUAS-Os within the unit and are nominated for local upgrade after attaining the minimum levels of flying hour experience, as specified in the appropriate AFI 11-5 MDS Volume 1. Unit-level instructors are responsible for conducting both MQT and CT. In the future, unit-level SUAS-O instructors may be the ideal candidates for developing an outstanding AETC SUAS-O IQT instructor cadre.

7.2.4. SUAS-O Candidate Selection

- Group 1. These SUAS are typically employed as ancillary sensors with a relatively low risk of mishap and collateral damage. As a result, Group 1 SUAS-O candidates may not require the same rigorous selection of students as Group 2-3 candidates. Other key factors to consider are some Group 1 candidates may not possess all spatial and decision-making skills required to employ Group 2-3 SUAS tactically.

- Group 2-3. Some form of aviation-aptitude screening should be required to maximize the probability of graduation while minimizing training costs and operational risk. “Washing out” candidates who demonstrate insufficient flying aptitude wastes valuable training allocations; as such, adopting a robust screening program is highly encouraged.

7.3. Current Training Environment

7.3.1. Undergraduate SUAS Flying Training

An Air Force general flying skills training course does not exist for Group 1-3 SUAS-Os. Platform skills are combined with IQT for each SUAS module. Those basic skills are specified in CJCSI 3255.01. Air Force SUAS-Os are trained to BUQ Level II, which qualifies SUAS-Os to operate in FAA airspace classes D, E, G and combat airspace.

7.3.2. Initial Qualification Training (IQT)

Currently, IQT is focused on ground-based SUAS-Os controlling a single UA. SUAS-Os are trained to perform basic airframe repairs and install replacement components from a field repair kit. More extensive repairs are performed at a depot, which is normally the vendor. IQT is typically provided through one of three methods:

- **Vendor-provided.** The UAS vendor is contracted to design and conduct IQT training for the Air Force. To be effective, the contract must specify the structure and content of the training as well as the approval authority. The Lead Command must review and approve the vendor-provided curriculum before acceptance for qualification training. Historically, vendor-provided training has been difficult to oversee as it is conducted at disparate locations and usually lacks access to suitable ranges, targets, airspace, and spectrum. In many cases, training was not satisfactorily completed due to limited oversight and/or resource allocation.

- **Contracted Instructor Services.** In some cases, contracted instructors teach government approved curriculum. This may be a stand-alone training course, or contractors may be hired to augment military or Civil Service instructors at a FTU. To be effective, contracted service performance must be closely supervised by the government. Stand-alone contracted instruction frequently suffers from the same resource shortfalls as the vendor-provided option unless a finite number of training sites are established and assured access to training resources is coordinated.

- **Service-Provided.** This method of training is conducted by military, Civil Service, and/or contracted instructors at an FTU with assured access to training resources. This has proven to be the most predictable and reliable source of training, often at significant cost savings, compared to the other options.

7.3.3. Mission Qualification Training (MQT)

MQT is the responsibility of the operational unit with the unit's MAJCOM approval of the curriculum for sufficiency. Due to the immaturity of training programs, there is little formal MQT documentation. Additionally, SUAS-O TTPs developed in combat have been poorly recorded, not well disseminated between units, and rarely incorporated into new MQT events. Conduct of MQT is subject to the same resource constraints as previously discussed. A common complaint of SUAS units is the lack of consistent access to suitable training ranges and airspace required for effective qualification.

7.3.4. Continuation Training (CT)

CT is required to maintain minimum levels of competency for safe SUAS operation. CT is conducted to gain experience, train TTPs, and refine tactical skills. CT is subject to the same training constraints previously discussed. It should provide the opportunity to periodically train with supported units to provide capability familiarity and to practice processing, exploitation, and dissemination of SUAS information. Without substantial individual initiative, CT reverts to the lowest common denominator of flying the minimum level required, with little opportunity to integrate into tactical exercises. Simulation may be used to fulfill a significant number of requirements, but not at the expense of practical experience. Special attention should be applied to ensuring crew coordination, weapons employment, and emergency procedures are sufficiently practiced, observed, and critiqued.

7.4. The Way Ahead

The quality of SUAS training greatly depends on whether or not SUAS operations remain an additional duty or if a career track is created for selected MDS's.

7.4.1. Group 1

Current Group 1 SUAS will remain an ancillary sensor capability, secondary to the mission and duties of the user (Battlefield Airman, Security Forces, Firefighter, Civil Engineer, OSI Agent, Combat Camera, etc.). In the future, Group 1 SUAS sensor capabilities and endurance will improve. They will also become more automated, and the HMI will become more intuitive and task-command oriented rather than flown dynamically. The present method of combining basic aviation knowledge and skills with specific SUAS IQT will continue to be sufficient for Group 1 training. However, employment of new software that enables multiple networked Group 1 SUAS and air-launched variants will require more detailed analysis of Group 1 operator workload. These growth areas will dictate the changes needed to training.

7.4.2. Group 2-3

Groups 2 and 3 SUAS capabilities, missions, and classes of airspace are much too complex for an additional-duty operator. Formal IQT and duty assignment is recommended to train and develop Group 2 and 3 SUAS-Os. This level of training will enable operators to attain Mission Ready (MR) status and gain extensive mission experience. Based on manned and unmanned aircraft aviation experience, continual rotation of newly trained personnel into – and experienced personnel out of – these more complex SUAS will facilitate the rapid development of an experienced SUAS community. The Air Force should create a new AFSC for the "Small UAS Operator" or expand current RPA crew duties to include Group 2 and 3 operations. Unfortunately, Group 4 and 5 operators are fully employed and have little capacity for additional requirements. In the short- to mid-term, creating a new air Force Specialty code may be the better alternative. However, even this option will be challenging as the Air Force must balance a force that has been reduced in size several times over the last 15 years.

- **Air Force Specialty Code.** If a new AFSC is generated, it should model the AFSOC SUAS FTU Program. At some point in the future, AETC may be tasked to conduct "Technical Training" for SUAS and leverage AETC's Undergraduate RPA Training (URT) program. The difference between the components of a SUAS and an RPA is scale and platform/sensor and mission complexity. The biggest discriminator is complexity of the mission, weapons release authority, and airspace access.

- **Maintenance.** Since Groups 2 and 3 SUAS have more complex airframe, power plant, control, sensor, and communications subsystems, they will require more extensive maintenance training than Group 1 SUAS. Depending on the specific MDS operating concept, maintenance may be performed by the SUAS-O team or the unit may require assignment of trained SUAS maintenance personnel. The SUAS Flight Plan recommends the Air Force conduct a formal maintenance training needs analysis IAW AFMAN 36-2234 to determine the appropriate solution.

7.4.3. Training Standards For Air-launched SUAS (AL-SUAS)

A determination must be made on training standards for AL-SUAS regardless of DoD Grouping. An AL-SUAS requires significant mission planning, coordination, UA control, and airspace management tasks to be employed effectively. AL-SUAS may be combined with an existing crew position depending on the level of mission planning automation and UA control. Some lessons may be applied from the current MALD CONOPS.

7.4.4. Effective Use of Simulation

- **High Fidelity Simulation.** Quality simulation is an indispensable tool for initial, mission, and continuation training. Concepts are illustrated and learned through interactive simulations, and flying and maintenance procedures taught and practiced. Mission planning scenarios and inflight changes are learned and practiced allowing new TTPs to be practiced or devised depending upon the fidelity of the simulation. Additionally, training for employment of multiple networked SUAS, air-launched SUAS, and long endurance missions would be excellent simulation scenarios.

- High quality, affordable simulation software is readily attainable, but requires competent engineering and operational oversight to develop realistic missions. Simulators must enable instructors and operators to easily design or modify scenarios suitable for realistic training in a variety of missions and operating environments. Beyond qualification training, simulation can enable realistic mission rehearsals. Distributed Mission Operations capability will integrate the training capability with supported units to build and maintain SUAS-O tactical experience. The Air Force should continue to mature a common online simulation environment to facilitate linkage of various remote simulators to facilitate cross-unit coordination and training. The Marine Corps uses such a system called Aviation Distributed Virtual Training Environment that links more than 40 aviation trainers for tactically relevant training.

- **Procedure and Menu Trainer.** Many flight training events may be more suitable in simulators. For example, certain emergency procedures are not safe to practice inflight and future SUAS options may include attritable mission sets. Additionally, SUAS-Os can use procedural simulators to train on repeatable tasks to become proficient in basic operations. A majority of RPA and SUAS operator proficiency is derived from being able to quickly navigate the various menus contained in the GCS software. While a simulator can provide this training, access can be limited for practicing menu navigation.

- A complement to such UAS simulators would be the use of simple menu trainer applications that can be loaded on a standard computer for personal use. The majority of the GCS menu software can be copied and recoded to function similar to the GCS. While this would require additional cost to develop and maintain, the added proficiency would reduce training time and enable the operator to maintain a higher currency level. SUAS technical orders (TO) currently contain hundreds of pages of walk-through menu diagrams; a menu trainer could be included as an attachment/replacement and act as a digital format of the TO pages.

- **Upgradability and Certification.** Simulators must be designed to keep pace with changes to SUAS and sensors. As new sensors, aircraft, and control stations are fielded, they also must be incorporated into training simulations. Designing SUAS simulation systems with growth capability enables required refinement of operator training. Formal simulator validation wil l verify the fidelity of fielded simulators and software. Simulator certification will verify the suitability of simulators to fulfill specific qualification and CT requirements.

- **Simulation Versus Live.** Active flying will still be required to build experience. Flying is a perishable skill that requires routine practice. A disciplined and challenging program that practices a variety of scenarios with increasing difficulty will develop operator habits that maintain peak proficiency. A quality SUAS-O training simulation enhances and reinforces skills learned from live flights and will ensure a high probability of mission success.

7.4.5. Common Ground Control Segment

A pivotal lesson learned over the last decade of UAS procurement, training, and operational use is the need for an interoperable, open-architecture common ground control segment (C-GCS). The C-GCS will reduce difference training timelines between similar UAS types, expand global UAS operations of participating systems, and ultimately save substantial costs when compared with stove-piped, proprietary GCSs.

In the case of training, a standard user interface (UI) enables a rapid learning curve between platform types and reduces training timelines with a more narrow focus on unique system attributes.

For operations, independent system GCSs around the globe could be significantly reduced with strategic positioning of C-GCSs to enable multi-system launch and recovery. Today, AeroVironment is the largest producer of DoD Group 1 SUAS and institutes a similar C-GCS concept within their company's family of systems. Each of their unique SUAS systems utilizes the same GCS and UI type. Once an operator is trained on any of the AeroVironment family of systems, additional platform training is significantly reduced and intuitively assimilated. This concept saves the DoD both training time and costs associated with independent platform-specific GCSs. The idea is to expand this internal company model into a DoD enterprise standard for all SUAS.

In the area of cost, a C-GCS has obvious advantages. Instead of industry adding a new, dissimilar GCS type for each platform, they would simply ensure interoperability with government-owned C-GCS software and hardware standards. Therefore, DoD would forego the costs of system-specific GCSs as industry builds to mil-spec standards. The Army and Marine Corps provide a noteworthy example of a Universal GCS concept with vehicle specific modules

(VSMs) that enables control of virtually any platform through a standard UI. Their UAS costs are reduced primarily by procurement of fewer proprietary GCSs and vast reductions in training. The Air Force can certainly learn from and utilize the successes of our sister Services and industry to move away from proprietary GCSs toward a more common, open-architecture GCS concept for the future UAS enterprise.

7.5. Complexity and Automation

Automation advancements have greatly exceeded what was known or implemented when our current fleets of SUAS and RPAs were procured. Over time, systems and operating environments have become increasingly complex, thereby elevating the risks associated with flexible, adaptable, and survivable operations. As a result, future development should acknowledge this reality with automated system enhancements. Historically and across the Services, UAS training system upgrades have lagged system modernization. In this vein, training the next generation of SUAS operators will require equally flexible and adaptable techniques through conceptual learning and visual simulation in order to keep pace with system modernization. The next generation of UAS will maintain some level of man-in-the-loop or on-the-loop control. As a result, the greatest limitation of successful SUAS employment will remain the human element and thus, the ability to train for an uncertain future must prioritize the operator first.

8. Conclusion

The Air Force stands at the proverbial cross-roads. An unpredictable, fiscally constrained, politically divisive policy and budget atmosphere defines the operating environment within which the smallest Air Force in our nation's history must operate. Demands for responsive and persistent airpower are driven higher than ever by the rise of near-peer nation-state expansionism, combined with regional instability at the hands of violent extremist organizations. The combat critical element of ISR alone has driven an insatiable demand greatly outpacing anything the Joint Force can provide. Meanwhile, global proliferation of technology continues to empower an increasing number of adversaries with capabilities once reserved only for "superpower" nations. This proliferation coupled with the decline of U.S. military budgets has led to the erosion of a once assured technological advantage that the nation has grown accustomed to taking for granted. Against this backdrop, RPA became an integral part of how the Air Force extended its global reach. To date, the Air Force has focused this evolution in air power on medium-to-high altitude systems based on their capacity, endurance, and range required to deliver strategic effects.

Conversely, the Departments of the Army and Navy led development of smaller unmanned systems supporting their tactical ground and fleet protection roles based on requirements for their assigned missions. Meanwhile, the delivery of SUAS to commercial markets is driving a "UAS revolution" fueling research, development, and production at a pace which holds strong potential to augment similar efforts within the defense industry. Capabilities once delivered only by large UAS are now found in the palm of one's hand. Rudimentary low-cost SUAS have also proven themselves to discretely find, fix, and track enemy combatants and resources, warranting further consideration for application within A2AD environments. These combinations of factors have transitioned the historically tactical-focused SUAS family of systems into platforms capable of delivering strategic capabilities required by our nation. However, the Air Force has yet to capitalize on these opportunities and is poised as the only military service yet to embrace SUAS with an acquisition program office, let alone a dedicated line of funding or effort to operationalize these capabilities. With the expansive maturation of SUAS, the Air Force has an opportunity to harness the power of the U.S.

technology edge to lead a new way of thinking about UAS. To capitalize on the exponential force multiplying effects provided by these systems, the Air Force must take a significant and aggressive approach to include SUAS as an integral part of our future force. This Flight Plan outlines an aggressive, but realistic vision on how to do just that.

The initial objective of this Flight Plan is to synchronize nascent efforts across a diverse set of stakeholders within the Air Force. In the near-term (within the FYDP), the Air Force must apply a substantial focus towards SUAS R&D. Due to SWaP-C technology advancements, the constraints which once restricted sensors and other enabling equipment to the larger UAS are no longer as severe. SUAS can not only carry equivalent sensors, they can also provide the persistence and range parameters required by the Air Force. Primary focus within this period must continue to apply current available capabilities to Air Force missions, while also unifying strategic direction across laboratory S&T efforts. Through these efforts, SUAS will allow the AF to "bend the cost curve" as good stewards of our nation's investments. Fiscal realities will continue to limit the development of exquisite large scale solutions and the modernization of our legacy fleets. SUAS development will counter-balance these challenges with capabilities that enable integration with existing assets, increase offensive options at a relatively low cost, and provide a distinct asymmetric advantage when facing our adversaries' defensive capabilities. However, the Air Force must avoid falling victim to an insular technical development focus. Though normal progression utilizes strategy and CONOP development to inform R&D, the rapid maturation and proliferation of SUAS technology, combined with the Air Force's late entry into this trade-space, dictates a parallel pursuit of strategy, CONOP and R&D development. Such a system must include an agile feedback loop ensuring an adaptive ability to inform development and ensure integration with existing and emergent Air Force weapon systems within the Air and Cyber domains.

As development is planned beyond the FYDP, the focus should trend towards increasing the capability of Airmen-Autonomy teaming. This development should harness the technical capabilities outlined in this Flight Plan while maintaining a central theme of enhancing, not replacing, the Airmen within the system. While the ratio of aircraft-to-Airmen will increase through concepts such as loyal wingman and multi-aircraft control, developers must remember that the Airmen are the strength of employing air power. Crucial to SUAS' success within the AF is the combat integration of well trained and resourced Airmen-Autonomy Teams as exponential force multipliers across the operating domains. Developing SUAS from this professional air-minded perspective will provide innovative operational concepts designed to extend the Air Force's global reach into denied airspace with minimal risk to either mission or Airmen. Within a 10-year period, the AF should see SUAS institutionalized, augmenting and/or replacing common capabilities currently found within the RPA fleet. SUAS institutionalization at this point includes maturation of a SUAS program office along with the establishment of a supporting force structure (squadrons, staff, etc.) responsible for training and equipping Airmen in the professional application of this emerging airpower advantage. It is also within this period where procurement and training cost savings are realized across the force.

Looking beyond the next decade, SUAS and RPA capabilities will have the potential to meet many C4ISR roles for the Air Force. Beyond ISR, Airmen will find themselves fully integrated while employing multi-role SUAS across the range of Air Force operations. By this point, "plug and play" modularity, scalable autonomy, and systems based on open system architectures will be common place. A sustainable logistics system for rapidly developed and acquired SUAS will ensure a highly adaptive family of systems. Through such efforts, operational concepts such as swarming will transition from R&D to Airmen delivering multi-domain effects within both permissive and non-permissive operational environments. Sense-and-avoid capability and adverse weather enhancements will enable access to all classes of airspace and weather conditions, making full UAS integration around the globe common place. When looking towards this future, one must remember that the pace of SUAS technological advancement is such that policy, guidance, and decisions set in motion today will directly affect combat capability 20 years from now. The costs of delaying this development are extended procurement timelines, increased costs, or at worst, increased combat risk within operating domains where asymmetric advantage is quickly fleeting. This only reinforces the fact that the Air Force must begin planning now for future SUAS capability enhancements to avoid being outpaced by our adversaries.

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APPENDIX A: LIST OF ACRONYMS

4G	Fourth Generation
6DoF	6 Degrees of Freedom
A2AD	Anti-Access Area Denial
AAO	Approved Acquisition Objective
ABSAA	Air-Based Sense and Avoid
ACS	Air Control Segment
ADS-B	Automatic Dependent Surveillance-Broadcast
AEF	Air and Space Expeditionary Force
AES	Advanced Encryption Standard
AETF	Air Expeditionary Task Force
AFI	Air Force Instruction
AFFOC	Air Force Future Operating Concept
AFOSI	Air Force Office of Special Investigations
AFPD	Air Force Policy Directive
AFRL	Air Force Research Lab
AFROCM	Air Force Requirements Oversight Council Memorandum
AFSC	Air Force Specialty Code
AFSFC	Air Force Security Forces Center
AFSOC	Air Force Special Operations Command
AGL	Above Ground Level
AI	Artificial Intelligence
ALN	Aerial Layer Network
ALOBS	Air-Launched SUAS Offboard Sensing
AL-SUAS	Air-Launched Small Unmanned Aircraft System
ALTIUS	Air Launched, Tube-Integrated Unmanned System
ASE	Airborne Security Element
ASF	Advanced Structural Fiber
AT&L	Acquisition, Technology, and Logistics
ATP	Allied Training Publication
ATR	Automatic Target Recognition
AVR	Air Vehicle Relay
BACN	Battlefield Airborne Communications Node
BDA	Battle Damage Assessment
BF	Backup Force
BLOS	Beyond Line-of-Sight
BSM	Battle Spectrum Management
BUQ	Basic Unmanned Qualification
C2	Command and Control

CAS	Close Air Support
CAT	Camper Alert Team
CCI	Controlled Cryptographic Item
CDD	Capabilities Development Document
CDMA	Code-Division Multiple Access
CFL	Core Function Lead
CFSP	Core Function Support Plan
C-GCS	Common Ground Control Segment
CJCSI	Chairman of the Joint Chiefs of Staff Instruction
CLS	Contract Logistics Support
COA	Certificate of Authorization
COIN	Counter Insurgency
COMCAM	Combat Camera
COMINT	Communications Intelligence
CONEMPS	Concepts of Employment
CONOPS	Concepts of Operation
CONUS	Continental United States
COP	Common Operating Picture
CPD	Capabilities Production Document
CRF	Convoy Response Force
CRG	Compliance Review Group
CS	Control Segment
CSAR	Combat Search and Rescue
CSMC	Combined Spectrum Management Cell
CT	Counter Terrorism/Continuation Training
C-UAS	Counter Unmanned Aircraft Systems
DARPA	Defense Advanced Research Projects Agency
DCGS	Distributed Common Ground System
DEAD	Destruction of Enemy Air Defense
DES	Data Encryption Standard
DoD	Department of Defense
DOTMLPF-P	Doctrine, Organization, Training, Material, Leadership, Personnel, Facilities, Policy
DSA	Dynamic Spectrum Access
EA	Electronic Attack
ELINT	Electronic Intelligence
EMS	Electro-Magnetic Spectrum
EO	Electro-Optical
EW	Electronic Warfare
FAA	Federal Aviation Administration

FIPS	Federal Information Processing Standard
FISINT	Foreign Instrumentation Signals Intelligence
FL	Flight Level
FMV	Full-Motion Video
FoS	Family of Systems
FPASS	Force Protection Airborne Surveillance System
FTU	Formal Training Unit
FY	Fiscal Year
G2M	GPS-Guided Munition
GBSAA	Ground-Based Sense and Avoid
GCS	Ground Control Segment
GEOINT	Geospatial Intelligence
GIISR	Global Integrated Intelligence, Surveillance, and Reconnaissance
GPS	Global Positioning System
GUI	Graphic User Interface
HAF	Headquarters Air Force
HALE	High-Altitude Long Endurance
HCE	Highly Contested Environment
HD	High Definition (Video)
HiDRA	High Dynamic Range Atom
HMI	Human Machine Interface
HVA	High Value Asset
IAA	Incident Awareness and Assessment
IADS	Integrated Air Defense System
IBS	Integrated Broadcast Service
ICAO	International Civil Aviation Organization
ICBM	Intercontinental Ballistic Missile
ICD	Initial Capabilities Document
IED	Improvised Explosive Device
IMINT	Imagery Intelligence
IMU	Inertial Measurement Unit
INF	Intermediate Range Nuclear Forces
IOC	Initial Operational Capability
IP	Internet Protocol
IQT	Initial Qualification Training
IR	Infra-Red
ISR	Intelligence, Surveillance, and Reconnaissance
JCA	Joint Capability Area
JCIDS	Joint Capabilities Integration Development System

JFC	Joint Force Commander
JMQ	Joint Mission Qualification
JMTL	Joint Mission Task List
JPO	Joint Program Office
JROC	Joint Requirements Oversight Council
JROCM	Joint Requirements Oversight Council Memorandum
JTAC	Joint Tactical Air Controller
JUMTS	Joint Unmanned Aircraft Systems Minimum Training Standard
JUONS	Joint Urgent Operational Needs Statement
KPP	Key Performance Parameter
KSA	Key System Attribute
LCCE	Life-Cycle Cost Estimate
LF	Launch Facility
LiDAR	Light Detection and Ranging
LMAMS	Lethal Miniature Aerial Munitions System
LOL	Loss of Link
LOS	Line-of-Sight
LPD	Low Probability of Detection
LPI	Low Probability of Intercept
LRE	Launch and Recovery Equipment
LWIR	Long Wavelength Infrared
MAC	Multi-Aircraft Control
MAF	Missile Alert Facility
MAJCOM	Major Component Command
MALD	Miniature Air Launched Decoy
MANET	Mobile Ad-hoc Network
MCMA	Materials with Controlled Microstructural Architecture
MDA	Milestone Decision Authority
MDS	Mission, Design, and Series
MFT	Mobile Fire Team
MIMO	Multi-Input Multi-Output
MQT	Mission Qualification Training
MR	Mission Ready
MSL	Mean Sea Level
MTI	Moving Target Indicator
MTW	Major Theater War
MUM-T	Manned-Unmanned Teaming
MWIR	Medium Wavelength Infrared
NAS	National Airspace System

NASA	National Aeronautics and Space Administration
NATO	North American Treaty Organization
NAWCWD	Naval Air Warfare Center Weapons Division
NDAA	National Defense Authorization Act
NSA	National Security Agency
NSE	Non-Standard Equipment
O&S	Operations and Support
OCO	Overseas Contingency Operations
OEM	Original Equipment Manufacturer
OFDM	Orthogonal Frequency-Division Multiplexing
OODA	Observe, Orient, Decide, and Act
OUSD	Office of the Under Secretary of Defense
P3I	Pre-Planned Product Improvement
PBFA	Policy Board for Federal Aviation
PBL	Performance-Based Logistics
PED	Processing, Exploitation, and Dissemination
PEO	Program Executive Office
PIC	Pilot in Command
PINS	Precision Inertial Navigation System
PnP	Plug and Play
PNT	Position, Navigation, and Timing
POI	Plans of Instruction
POR	Program of Record
QDR	Quadrennial Defense Review
QRC	Quick Reaction Capability
R&D	Research and Development
RAM	Reliability, Availability, and Maintainability
RCS	Radar Cross Section
RF	Radio Frequency
ROBE	Roll-On Beyond-Line-of-Sight Enhancement
ROMO	Range of Military Operations
ROVER	Remote-Operated Video Enhanced Receivers
RPA	Remotely Piloted Aircraft
RSTA	Reconnaissance, Surveillance, and Target Acquisition
RVT	Remote Video Terminal
SA	Situational Awareness
SAASM	Selective Availability, Anti-Spoofing Module
SAM	Surface-to-air Missile
SAR	Synthetic-Aperture Radar

SBIR	Small Business Innovation Research
SCAR	Strike Coordination and Reconnaissance
SD	Standard Definition (Video)
SEAD	Suppression of Enemy Air Defense
SEGM	Scan Eagle Guided Munition
SET	Security Escort Team
SIGINT	Signals Intelligence
SKL	Simple Key Loader
SMP	Strategic Master Plan
SOC	Special Operations Center/Command
SOWT	Special Operations Weather Team
SPAN	Self-Powered Ad-hoc Network
SPO	System Program Office
SRaP	Speed, Range, and Persistence
SRT	Security Response Team
STANAG	Standard Agreement
STUAS	Small Tactical Unmanned Aircraft System
SUAS	Small Unmanned Aircraft System
SUAS-O	Small Unmanned Aircraft System Operator
SURGE-V	Small Unmanned Renewable Energy Long Endurance Vehicle
SWaP-C	Size, Weight, and Power plus Cooling
SWIR	Short Wavelength Infrared
TO	Technical Order
TOBS	Tactical Offboard Sensing
TRF	Tactical Response Force
TTP	Tactics, Techniques, and Procedures
TUDLS	Total Urban Dominance Layered Systems
UAS	Unmanned Aircraft System
UAV	Unmanned Aircraft Vehicle
UGS	Unattended Ground Sensor
UI	User Interface
UJTL	Universal Joint Task List
UONS	Urgent Operational Needs Statement
URT	Undergraduate Remotely Piloted Aircraft Training
USAF	United States Air Force
USMC	United States Marine Corps
USSOCOM	United States Special Operations Command
VFR	Visual Flight Rules
V-NIIRS	Video National Imagery Interpretability Rating Scale

VSM	Vehicle Specific Module
VTOL	Vertical Takeoff and Landing
WAAS	Wide-Area Airborne Surveillance
WAMI	Wide-Area Motion Imagery
WNaN	Wireless Network after Next

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APPENDIX B: STRATEGIC MASTER PLAN LINKAGES

The Strategic Master Plan (SMP) translates the United States Air Force's 30-year strategy, *America's Air Force: A Call to the Future*, into comprehensive guidance, goals, and objectives. The complete SMP consists of a core narrative, goals, objectives, and four annexes: the Human Capital Annex (HCA), Strategic Posture Annex (SPA), Capabilities Annex (CA), and the Science and Technology Annex (STA). The core SMP will be updated every two years, while the annexes may be revised annually, as required. The SMP and associated unclassified strategic documents are located at: *http://www.af.mil/Airpower4America.aspx*

The classified CA and STA can be found on the SIPRnet Portal.

The mapping below provides connectivity of SMP goals and objectives to the Small Unmanned Aircraft Systems (SUAS) Flight Plan (FP) concept of operations (CONOPS) and technology initiatives. *Direct* links mean this FP offers concepts and initiatives that may directly enable SMP goals and objectives, based on decisions by Air Force senior leadership. *Support* means this FP supports other initiatives that may enable SMP objectives, while *Tertiary* means SUAS can be one of many possible solutions or an enabler of other approaches with strategic impact on the Air Force.

The strategic vectors are to:

- Provide effective 21st-century deterrence (**DTR**)
- Maintain a robust and flexible global integrated ISR capability (**ISR**)
- Ensure a full-spectrum-capable, high-end-focused force (**FH**)
- Pursue a multi-domain approach to our five core missions (**MDA**)
- Continue the pursuit of game-changing technologies (**GCT**)

The figure below depicts the naming convention; in this example for SPA objectives (CA objectives use the "C" identifier).

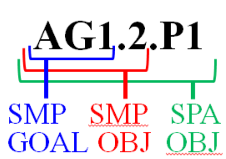

Figure A-1: SMP Naming Convention

AG1.4 Combine training across multiple mission sets, including integrated Live-Virtual-Constructive (LVC) venues and operator-in-the-loop Modeling and Simulation (M&S), to cultivate Airmen trained in agile and robust decision-making to devise multi-domain solutions to complex problems in uncertain, contested environments.	
AG1.4	Tertiary
AG1.4.P5	Tertiary

AG2.1 Ensure systems are designed, engineered, tested, acquired, and sustained smartly, efficiently, and cost-effectively. As integrator, the Air Force will define technical baselines and common architectures and ensure modularity and responsiveness to Airmen's needs in a dynamic strategic environment.	
AG2.1	Direct
AG2.1.C1	Direct
DTR.2 Develop, test, and implement additional non-nuclear capabilities that deter a wide range of adversaries, including non-state actors, and assure allies and partners. Consider low-cost measures that generate high-cost adversary responses.	
DTR.2.	Direct
DTR.2.C1.	Direct
DTR.2.C2.	Direct
DTR.2.C3.	Tertiary
ISR.1 Rebalance resilient ISR sensors, systems and processes toward operations in high-end contested environments, and focus on moderately priced systems, to include commercial technology, for permissive environments.	
ISR.1	Direct
ISR.1.C1	Direct
ISR.1.C2	Direct
ISR.1.P1	Support
ISR.1.P3	Support
ISR.1.P4	Tertiary
ISR.1.P4.a	Support
ISR.1.P4.b	Support
ISR.1.P4.c	Support
ISR.2 Develop a robust, survivable, and secure architecture to connect and integrate ISR operations across all domains, ensuring that collection and analytic systems (including non-traditional ISR platforms and sensors) and users can collaborate seamlessly.	
ISR.2.C1	Direct
ISR.2.C2	Tertiary
ISR.2.C3	Tertiary
ISR.2.C4	Tertiary
ISR.2.C5	Direct
ISR.2.C6	Direct
ISR.2.C7	Tertiary
ISR.3 Increase flexibility and standardization in ISR processes and knowledge management tools to minimize delays and regulatory obstacles, enabling analysts to provide rapid, decision-level intelligence to overcome adaptive adversaries.	
ISR.3.C1	Tertiary
ISR.3.C2	Tertiary

ISR.3.C3	Direct
ISR.4 Enhance capabilities to holistically detect, monitor, analyze, and attribute threats (kinetic or non-kinetic), adversaries, and their support networks, and improve target systems analysis in order to determine the best way to act on this intelligence.	
ISR.4.C1	Support
ISR.4.C2	Support
ISR.4.C3	Support
ISR.4.C4	Support
ISR.4.C5	Direct
ISR.4.P1	Support
ISR.4.P2	Support
ISR.4.P3	Support
FH1.1 Ensure the ability to gain and maintain the required degree of control of the air to prevent effective enemy interference with friendly operations.	
FH1.1	Tertiary
FH1.1.C1	Support
FH1.1.C2	Tertiary
FH1.2 Ensure viable options are available to sustain capabilities provided by space assets in case they are challenged or denied, particularly for position, navigation, timing, strategic warning, and communications. This includes both resilient space systems and non-space options.	
FH1.2.C2	Support
FH1.2.C4	Direct
FH1.4 Enhance abilities to degrade or deny situational awareness and targeting ability to an advanced enemy.	
FH1.4	Support
FH1.4.C1	Support
FH1.4.C2	Tertiary
FH1.4.C4	Tertiary
FH1.5 Reduce emphasis on tactical tasks in permissive environments where other Services have sufficient organic capacity (for example tactical ISR, fire support, and intra-theater mobility).	
FH1.5	Direct
FH1.5.C1	Direct
FH1.5.C2	Tertiary
FH1.5.C3	Tertiary
FH2.1 Increase emphasis on research, development, testing, and evaluation (RDT&E) for capabilities that ensure the ability to find, fix, track, target, engage, and assess effects against critical target sets in highly contested environments.	
FH2.1	Direct

FH2.2 Increase emphasis on stand-off capabilities that maximize speed, range, and flexibility, while maintaining the ability to transition to effective, resilient presence in the battlespace.	
FH2.2	Direct
FH2.2.C1	Support
FH2.2.C2	Direct
FH2.2.C3	Direct
FH2.5 Ensure rapid, robust global mobility by developing and maintaining smart and adaptive global and theater distribution networks to ensure the most efficient movement and positioning of materials, and by leveraging advanced design and manufacturing.	
FH2.5	Support
FH2.5.P3.b2	Direct
FH2.6 Improve execution speed and situational understanding through advances in human-machine teaming, automated processing, exploitation, and dissemination (PED), analysis, and updated C2 and communication capabilities.	
FH2.6	Tertiary
FH2.6.C2	Support
FH2.7 Provide resilient installations, infrastructure, and combat support capabilities that enable the Air Force to project power rapidly, effectively, and efficiently.	
FH2.7	Direct
FH2.7.C1	Direct
FH2.7.C2	Direct
MDA.1 Orient the Air Force to a mindset that intuitively considers multi-domain options when solving complex problems, to include the development of doctrine and tactics, techniques, and procedures (TTPs).	
MDA.1	Support
MDA.1.C1	Support
MDA.2 Reappraise existing compartmentalization practices and eliminate institutional barriers to empower Airmen and organizations to employ multi-domain approaches.	
MDA.2	Tertiary
MDA.2.P2	Tertiary
GCT.2 Provide senior leadership with timely S&T options, best matched to the security environment, that maintain or advance asymmetric advantages in air, space, and cyberspace and that inform and accelerate capability development through experimentation campaigns and developmental planning efforts.	
GCT.2	Support
GCT.2.C1	Support

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