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A Framework for Aligning Emerging Small UAS Technologies With Defense Acquisition Processes

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Abstract

Small unmanned aircraft systems (SUAS) are increasingly important for ground combat operations. SUAS extend ground unit situational awareness and their ability to prosecute targets, and may enhance command and control. Their fast development cycles, commercial availability, and still-maturing operational concepts, though, do not align well with conventional U.S. Department of Defense (DoD) force development processes and timelines. This paper proposes a framework to address this misalignment by rapidly capturing unstructured qualitative insights on SUAS usage and converting them into procurement and allocation levels within the context of existing force development processes. The process leverages semi-structured interviews and document collection for data collection, followed by a mixed method approach using qualitative coding and mathematical matching. The result is a set of procurement and allocation levels that balances current operational needs with opportunities for experimentation and concept development.

Introduction

Current Marine Corps operations and future operating concepts place a heavy emphasis on disaggregated and distributed operations (U.S. Marine Corps, 2016). Such operations require high demand, low density capabilities such as aerial imagery and command, control, communications, computers (C4) assets to provide battlefield awareness. Currently, the Marine Corps centralizes many of these assets at regimental or higher echelons. This approach is inadequate to provide support to subordinate units conducting disaggregated and distributed operations. As such, the Marine Corps has seen an increased demand for organic means of enhancing battlespace awareness at the company level and below. To meet this growing demand, the Marine Corps has invested in emerging small unmanned aircraft system (SUAS) technology which provides small units with not only organic situational awareness capabilities, but also other capabilities that were once exclusively held at higher level units. The Marine Corps has been experimenting with these platforms for over 15 years and has accelerated its efforts to integrate SUAS into operations.

However, the Marine Corps is still refining its requirements for this maturing technology. The analyses that drive requirements are incomplete. Other platforms have been acquired through the rapid acquisition process. The current acquisition approach has focused on ground combat elements, primarily infantry units, but the expectation is that other unit requirements will expand rapidly when other elements are considered.

Additionally, SUAS technology advances are being influenced by commercial factors that may crowd out military ones.[1]

The Marine Corps has identified that a comprehensive review of the SUAS portfolio is required. This review will help determine what capabilities are needed across the Marine Air Ground Task Force (MAGTF) and where there are current gaps. The purpose of this research is to document lessons learned from the Marine Corps' recent experience and recommend next steps in SUAS allocation and procurement.

Research Approach

For this research, SUAS are defined as unmanned aircraft systems (UASs) in Department of Defense (DoD) UAS Groups 1 and 2; these systems weigh less than 55 pounds, fly lower than 3,500 feet above ground level (AGL), and fly no faster than 250 knots. Groups 1 and 2 encompass a wide span of capabilities. We further define SUAS using the seven emerging categories used by U.S. Special Operations Command (USSOCOM) Expeditionary Organic Tactical AISR Capability Set (EOTACS) to further refine DoD Groups 1 and 2.[2] These seven categories are explained in Table 1. In particular, we use the performance characteristics of each EOTACS category to frame our procurement analyses and recommendations in later chapters. Note that Category 1 consists of tethered platforms and is not considered SUAS and thus not considered in our research.

[1] Facilitator interview

[2] AISR: airborne intelligence, surveillance, reconnaissance

Table 1. USSOCOM EOTACS Categories Considered in This Analysis
(U.S. Special Operations Command, 2018)

Characteristic	Threshold Specification	Categories 2 Nano VTOL	3 Micro VTOL	4 SR/SE VTOL	5 SR/SE FW	6 MR/ME FW	7 LR/LE FW
Payload	Electro-optical/infrared (EO/IR)?	Yes	Yes	Yes	Yes	Yes	Yes
	Payload threshold weight (lbs)	0	0	1	1	2	10
Endurance	Endurance (hours)	0.2	0.2	0.5	0.5	2	6
Speed	Cruise (knots-indicated air speed, KIAS)	10	15	20	20	25	25
	Dash (KIAS)	10	15	20	35	35	35
Weight	Min (lbs)	0	0	3	0	0	20
	Max (lbs)	1	3	10	20	20	55
Launch	Hand?	Yes	Yes	Yes	Yes	Yes	Yes
	Rail?	No	No	No	Yes	Yes	Yes
	Vertical Take-off and Landing (VTOL?)	No	No	No	Yes	Yes	Yes
	Bungee	No	No	No	No	No	Yes
	Tether?	No	No	No	No	No	No
Recovery	Runway-independent?	Yes	Yes	Yes	Yes	Yes	Yes
	Deep stall?	No	No	No	Yes	Yes	Yes
	Sliding (belly land)?	No	No	No	Yes	Yes	Yes
	Combination?	No	No	No	Yes	Yes	Yes

Note. VTOL: vertical takeoff and landing, FW: fixed wing, SR: short range, SE: short endurance, MR: medium range, ME: medium endurance, LR: long range, LE: long endurance

Assumptions and Limitations

Like any research, this effort was bounded by various assumptions and practical constraints. We identify them here at the outset of this report.

- This research only addresses SUAS needs for CE and GCE units from the squad to regimental level.
- This research is confined to examining material solutions.
- The mathematical matching methodology errs on the side of inclusivity when it comes to linking SUAS platforms and categories to definable mission tasks.
- This analysis is budget-unconstrained as it assesses CE and GCE SUAS employment today, along with future needs, and develops an idealized future state to inform decision makers considering future SUAS procurement.
- Costs are representative of current models for each category and are current as of October 2018.
- Procurement recommendations do not include platforms already in Marine Corps possession.

- We did not consider the effect that task-organized units (i.e., Marine air ground task forces) might have on reducing the number of platforms needed.
- At the request of the sponsor, our quantities do not take attrition or additional maintenance float requirements into consideration.

A Literature Review Identified Decision Paths and Outcomes of Actions That the Marine Corps Has Already Taken

To capture the Marine Corps' baseline SUAS usage, we reviewed a variety of after action reviews (AARs), reports, and open-source literature to understand the work that the Marine Corps has already done to develop its SUAS capability. This body of work spanned over 10 years and helped us understand the previous analyses, decisions, and problem areas that have informed the Marine Corps' SUAS efforts. In particular, they helped us identify five mission profiles that encompass the different ways the Marine Corps may use SUAS (exemplar sources are cited):

- **Situational awareness:** Increase small-unit commanders' ability to visualize the battlefield to speed their decision-making process (Dalby, 2013).
- **Force protection:** At the small-unit level, provide standoff detection ability to detect and inspect improvised explosive devices (IEDs) or unexploded ordnance (UXO) to allow freedom of maneuver (Gillis, 2017).
- **Rapid target engagement:** Increase small-unit commanders' ability to identify, locate, and engage targets, particularly time-sensitive ones (Dalby, 2013).
- **Persistent C4:** Increase small units' abilities to communicate through voice and data, particularly at beyond line of sight (LOS) ranges or dense terrain that suppresses signals (NCOs, SNCOs, & Officers of 3d Bn 5th Marines, 2017).
- **Persistent electronic warfare (EW):** Provide small units with the ability to sense and affect the electromagnetic spectrum for military purposes (Turnbull, 2019).

Semi-Structured Interviews and Qualitative Coding Systematically Revealed Operational Insights From Current Users

To assess how well the Marine Corps is employing its SUAS to fulfill those mission profiles today, we conducted and analyzed a series of semi-structured interviews. Interviews provided direct access to personnel intimately involved in managing and employing SUAS. We developed and followed semi-structured protocols that encouraged discussion about how SUAS are currently employed, how they might be employed in the future, the force development process, and sustainment. We opted for semi-structured interviews to encourage greater consistency across interviewees while allowing the flexibility to explore relevant subject areas that we did not anticipate during protocol development. Our literature review suggested three different interview groups, and our protocols were tailored to focus on areas most relevant to each:[3]

- **Sponsors** that articulated how the SUAS serves Marine Corps purposes. This included HQMC(CD&I) and PMA-263. Protocols focused on future employment, force development, and sustainment.

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[3]Although we focused on certain interview areas for each group, all groups were given the opportunity to discuss all interview areas.

- **Facilitators** that enable SUAS employment, such as training and logistics support agencies (TALSAs), MCTOG, VMXs, and Defense Innovation Unit (DIU). Protocols were focused on force development and sustainment.
- **Operators** that employ the SUAS, which mostly consisted of unit SUAS program managers from division to battalion level.[4] Protocols were focused on current employment, future employment, and sustainment.

We interviewed 69 individuals across 39 organizations between May and November 2018. We conducted interviews in person at Marine Corps and DoD installations across the continental United States (CONUS) and over the phone. In addition to interviewing HQMC sponsor and facilitator organizations, we interviewed at least one unit of each type from the CE and GCE.

Thematic Analysis

We explored the collected literature review and interview data through qualitative coding and thematic analysis. To ground our analysis. we developed a code tree with themes we were interested in exploring. The code tree was based on initial themes that emerged from the literature and interviews, including the utility of various SUAS mission profiles, preferred SUAS design characteristics, employment, and sustainment issues. All interviews were coded by two team members using Dedoose thematic analysis software (De Vries et al., 2008).[5] This activity was particularly important in enabling us to quantify the qualitative data captured in the interviews (e.g., priority of SUAS design characteristics) and understand its ordinality. In addition, coding captured tones and sentiments that helped us more comprehensively understand the underlying connotations interviewees associated with various aspects of SUAS. Emergent relationships observed in coding were used to guide and inform other aspects of the research approach.

The interview results, in conjunction with the review of source documentation, allowed us to examine a variety of themes across and between different interviewee perspectives (e.g., HQMC versus operating forces, CE versus GCE, and different OccFlds and echelons). This analysis forms our assessment of the current state of SUAS in the Marine Corps, explored in the following three themes.

Mathematical Matching Helped Identify the Best SUAS for Each OccFld and Echelon

To systematically relate the insights from the literature review and interview themes into procurement and allocation recommendations, we took several steps to convert the qualitative data into quantitative proxies. We used a mathematical matching method to transform the qualitive data into ideal SUAS design characteristics for each occupational field (OccFld) and echelon, then allocated them to CE and GCE units. This yielded a set of procurement and allocation courses of action for the Marine Corps to consider. Model inputs can be changed, allowing the Marine Corps to conduct additional analysis using different assumptions or units of interest.

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[4]Although we interfaced with units no smaller than battalions, they provided us with access or perspective on lower echelons, down to the squad level.

[5]To ensure consistency of coding by all coders, inter-rater reliability was tested using Cohen's kappa. The two coders involved in this project achieved a 0.91 kappa score, indicating almost perfect agreement.

Complementary Data Sources Shaped the Ideal SUAS Profile for Each OccFld and Echelon

To convert the qualitative data into quantitative proxies, we considered three additional data sets to give depth and rigor to the process:

- The 1,242 training and readiness (T&R) tasks that define tasks for each OccFld and echelon of interest
- EOTACS framework, including representative costs
- Descriptions of the five SUAS mission profiles

Each data source complements the others, forming a broad understanding of how SUAS may be useful for a given OccFld-echelon combination. T&R tasks define the entire range of tasks that a given OccFld-echelon combination is required to perform, but do not offer information about how SUAS might fit into a task. Interview data provided information on how SUAS might help an OccFld-echelon combination perform its mission generally, but not at the detailed level described in the T&R manual. The EOTACS framework helps us delineate different levels of capability between SUAS. Lastly, the SUAS mission profiles paint a detailed picture of how SUAS might help with Marine Corps missions generally but does not characterize how they might help any given OccFld-echelon combination.

Combining the data allowed us to articulate the ideal SUAS design profile for each OccFld-echelon combination. Note that interview inputs were necessarily limited to ordinal preferences and some design characteristics were subjective.[6] To accommodate this (and to make the ideal SUAS design profile relatable to existing classes of SUAS), we converted all preference data into rankings of the importance of each design characteristic for each T&R task for each mission profile.[7]

For instance, consider the infantry battalion task of conducting a ground attack (T&R task INF-MAN-7001). Rankings were informed by interview inputs and the research team's understanding of each T&R task definition and mission profile description. On that basis, SUAS situational awareness capabilities would be useful in this regard, but not force protection, rapid target engagement, persistent C4, or persistent EW. Within the situational awareness task, a SUAS' endurance is the most important priority. Speed is the next priority, followed by payload carrying capacity, weight, and launch and recovery flexibility. This process was repeated for all 1,242 T&R tasks related to the OccFlds and echelons of interest for this research. If a task did not apply to a mission profile, then it was assigned a null value. See Figure 1 for a graphical example.

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[6] For instance, it would be difficult for an interviewee to articulate a response to our question about design preferences with a numeric answer such as specific speed or payload carrying capacity. Rather, we asked for a general ranking of the design characteristic. Nevertheless, an ordinal preference does not indicate how close either ideal specifications or platforms might be to each other. In reality, platforms might be quite comparable, but ordinal rankings force a distinct prioritization, which could distort choices.

[7] Embedded in each individual T&R task is the OccFld and echelon that it applies to; no T&R task is applied to more than one OccFld echelon combination.

Event Code	Task	Situational Awareness: Weight	Speed	Endurance	Payload Weight	Launch	Recovery
INF-MAN-7001	Conduct a ground attack	4	2	1	3	5	5
INF-MAN-7101	Conduct a position defense	3	2	1	2	4	4

RAND interview protocol question 13: Can you rank the most critical design features of a SUAS?

Example response: *"Range is huge....If we could improve battery life we'd have to bring Raven down less often, that [would] be best"*

Figure 1. Example of Training & Readiness SUAS Design Characteristic Ranking

Note. Source: RAND analysis

The result was a set of 37,260 individual ranking sets.[8] To generalize this information down to an ideal SUAS profile, we took the average of all ranking sets for each OccFld-echelon combination. Note that we considered all T&R tasks to be equally important to the overall functioning of an OccFld-echelon combination.[9] However, we did consider the relative importance of each mission profile to each OccFld-echelon combination. In this case, we opted to weight the situational awareness mission 1.5 times the other mission profiles, as it was the one that was most consistently mentioned in interviews. The ultimate result is a ranking of the importance of the six SUAS design characteristics for each OccFld-echelon combination. See Figure 2 for a graphical example.

		Situational awareness						Force protection					
		Wt	Spd	End	P-Wt	Lnch	Rvry	Wt	Spd	End	P-Wt	Lnch	Rvry
INF-MAN-6102	Conduct a mobile defense	4	2	1	3	5	5	4	2	1	3	5	5
INF-MAN-6103	Conduct retrograde	4	2	1	3	5	5	4	2	1	3	5	5
INF-MAN-6201	Operate in an environment with an Improvised Explosive Device (IED) threat	4	2	1	3	5	5	4	2	1	3	5	5

T&R rankings averaged and rounded up to nearest whole number by echelon, OccFld…

…then averaged across mission profiles; most important mission identified by interviewees weighted 1.5x

Figure 2. Aggregating Preference Inputs Into Ideal SUAS Profiles

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[8] From 1,242 rankings multiplied by six design characteristics, multiplied by five mission profiles.

[9] This can be reinvestigated by other, more knowledgeable experts if needed.

Note. Source: RAND analysis

Matching Ideal Profile to SUAS Design Characteristics

The next step is to identify the EOTACS category that best meets the ideal design profile articulated by a given OccFld-echelon combination. To do this, we used a common method for ranking complex preferences, known as the analytical hierarchy process (AHP), with some modifications.

We Modified an Analytical Hierarchy Process to Accommodate Ranked Preferences

The standard AHP takes as its inputs matrices of pairwise comparisons between characteristics (Satty, 1986). These pairwise comparisons specify which of each pair is more suitable—and by how much—according to a prescribed mapping of verbal descriptions of relative suitability to numeric scores.

In standard AHP, the verbal descriptions enable analysts to directly compare the direction and magnitude between a pairwise comparison.[10] Since our interviewees were only able to respond with design preferences in ranked order, we modified the AHP methodology by expressing a unit's numerical capability requirement profile as a single vector ranking the relative importance of each SUAS characteristic. Similarly, because units have not had the opportunity to establish specific platform-agnostic technical specifications, we converted the technical specifications of platform categories to rankings of each category for each characteristic. For example, the category with the fastest speed was ranked 1 for speed. See Table 2 for a graphical depiction of this arrangement.

Table 2. Ranked SUAS Design Characteristics

Design characteristic	Directionality	Cat 1 Tethered	Cat 2 Nano VTOL	Cat 3 Micro VTOL	Cat 4 SR/SE VTOL	Cat 5 SR/SE FW	Cat 6 MR/ME FW	Cat 7 LR/LE FW
Endurance	Longer is better	1	5	5	4	4	3	2
Speed	Faster is better	5	4	3	2	2	1	1
Weight	Less is better	6	1	2	3	4	4	5
Payload capacity	Heavier is better	2	4	4	3	3	2	1
Launch	More options are better	3	2	2	2	1	1	1
Recovery	More options are better	3	2	2	2	1	1	1

Note. Source: RAND analysis

We next applied the modified AHP algorithm to compare the ideal SUAS profiles to the converted EOTACS categories. Our modified algorithm was originally developed in R

[10] For example, consider an interview with a car enthusiast about engine preferences. The interviewee can respond with specific horsepower or liter displacement preferences. Since these design preferences can be articulated as quantitative values, the direction and magnitude of the preferences (expressed as Euclidian distances) can be evaluated directly.

and later adapted to VBA to facilitate wider compatibility with USMC computers. The following steps illustrate each transformation in the algorithm:

- Ranked EOTACS profile is read in and reversed such that higher values represent better performance in a category. This was done to facilitate modified pairwise comparisons.
- Aggregated unit preference averages are read in using the VBA macro.
- A pairwise matrix is constructed by taking the ratio of each ranked design characteristic to each other. For example, the weighted rank for endurance is compared to the weighted rank for payload carrying capacity by dividing the weighted rank score by the weighted endurance score. The matrix yields 36 ratios, which are then summed by column.
- A normalized matrix is created by dividing each cell value from the modified pairwise matrix by the sum of the respective column from the same matrix. The average of each row yields the weight of a given design characteristic for each OccFld-echelon combination.
- The dot-product of the design characteristic categories for each SUAS and the weight vector created in the previous step yields a score value for each EOTACS category. The highest score indicates the optimal match.

The process is repeated for each OccFld-echelon combination. The resulting scores yield a complete ranking of each EOTACS category to each OccFld-echelon combination from best to worst fit.

These analytical outputs are not prescriptive. Like any process, we expect the modified AHP to have some shortcomings (see the next section), given how much we reduced and generalized the starting inputs. Rather, these outputs should be considered as the starting point for further evaluation of the optimal EOTACS category for a given OccFld-echelon combination.

Modified AHP Has Some Shortcomings

Our modified AHP reduces match quality by compressing both the Euclidean distance between units with different priorities and between SUAS categories with different capabilities.[11] In this specific application, these modifications likely did not affect match results because SUAS categories vary most significantly along discrete dimensions, such as whether a category offers vertical take-off and landing (VTOL). As the SUAS market matures and more specialized platforms become available, users can increase the fidelity of this model by

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[11] For example, consider comparisons between two different pairs of platforms along the dimension of endurance. Suppose that for the first pair, the highest ranked platform has a maximum endurance of 10 hours and the second ranked platform has an endurance of 9.5 hours. Suppose that for the second pair, the top ranked is 10 hours and the second ranked is only five hours. The endurance of the first pair is so close that it might be preferable to go with the second ranked platform if, for example, it is significantly less expensive or superior along another performance dimension such as speed. In contrast, the difference between the second pair is significant, and the first platform is likely preferable for a unit requiring longer endurance, even at the expense of greater cost or other performance features. Our modified AHP cannot distinguish between these two situations in the same way the standard AHP with pairwise rankings can.

- establishing capability-based, platform-agnostic technical requirements where possible (i.e., the maximum acceptable decibel signature for a unit) for subsequent use in a quantitative matching algorithm, and
- where requirements cannot be expressed in quantitative terms, generating full pair-wise comparison matrices in order to employ the standard AHP, rather than ranking across characteristics.

To identify the SUAS categories best satisfying unit capability requirements, we input both the SUAS category capability rankings and unit capability requirements profiles into the AHP algorithm, which mathematically identified the best matched SUAS category for each unit's capability requirements profile.

We Developed Quantity Recommendations From Literature Review and Interview Inputs

Having identified the best EOTACS category (or categories) for each OccFld and echelon, we estimated the total quantity of platforms needed to usefully carry out the missions that SUAS might be useful for. For each OccFld-echelon combination, we considered interview inputs, unit AARs, unit CONEMP and CONOP slides, the Marine Operating Concept, and current unit organization documents to identify the needed quantity of each EOTACS category. In some cases, some OccFlds had highly developed CONEMPs and CONOPs that illustrate concepts and plans for how SUAS might be employed within the context of an operation. These slides often included recommended quantities and types of SUAS needed to accomplish a given mission. In other cases, we had to infer and estimate the number.[12] We then scaled that quantity up so as to equip all units in a given OccFld-echelon combination. Finally, we considered a slightly reduced allocation to capitalize on the Marine Corps' existing TALSA investments to manage a pooled SUAS fleet for units that are less mature in their SUAS employment concepts.

Results

Our results are divided into two sections. First, qualitative insights on the current state of SUAS in the Marine Corps indicate a greater need for access to platforms in order to fully determine what the optimum quantity and type of SUAS might be. Second, we offer a set of three procurement and allocation recommendations that fulfill the access need to varying degrees.

Current State of SUAS in the Marine Corps

The thematic analysis identified three key results about the current state of SUAS in the Marine Corps.

Marine Corps Occupational Fields Only Partially Grasp What SUAS Mission Profiles Are Useful to Them

Based on our thematic analysis, we found that Marine Corps CE and GCE units understand and value the utility of some SUAS mission profiles, but the utility of other

[12] We inferred quantities in such cases by reviewing doctrine, T&R standards, and emerging concepts (described in the Marine Operating Concept) to identify how many of each type of SUAS would need to be used by a given unit and how many units would have to employ SUAS simultaneously.

profiles remains unclear. Recall from the Research Approach chapter that the Marine Corps identified five mission profiles: (1) situational awareness, (2) force protection, (3) rapid target engagement, (4) persistent C4, and (5) persistent EW. Almost all units shared numerous and substantial observations about situational awareness and force protection mission profiles. When asked how their units currently employ SUAS, interviewees discussed tasks that corresponded to the situational awareness mission profile 97 times in 29 of 42 interviews. Tasks related to the force protection mission profile were mentioned 51 times in 32 interviews. One excerpt from a light armored reconnaissance (LAR) unit indicates the familiarity and appreciation for the ability of SUAS to enhance situational awareness:

> I think the situational awareness … the idea behind [the RQ-11B Raven] is for preliminary reconnaissance before the vehicles go up. See the route, identify manmade or natural obstacles and whether or not we should even try.

Even units that did not have much experience with SUAS shared substantive observations about how they *would* employ SUAS for these mission profiles. A reconnaissance interviewee who had only used SUAS sporadically in the past illustrates a level of appreciation for it, much the same as we saw in the previous excerpt:

> [The] key benefit is providing offset from our objective[;] it avoids big compromise problems. It allows us to gather information without being close.

Another interviewee from an artillery unit (a community that did not indicate frequent SUAS usage) discussed both its usage for situational awareness as it is described in this context and also for understanding its own force signature:

> [We use SUAS] to fly red cell. Training batteries use them to understand new threat dimension, to look to the sky. This is not something were used to thinking about. We do lots of red cell work, [as well as] assessment of our own signature, what we look like.

These and other responses indicate that CE and GCE units understand how SUAS can enable both mission profiles and what the concepts of employment may entail.

However, the other three mission profiles were less frequently commented on or understood. Rapid target engagement was mentioned 56 times, but only in 13 interviews. Interestingly, some units professed deep experience in using SUAS for rapid target engagement, but others did not. An infantry interview excerpt illustrates the almost casual and pedestrian nature of using SUAS for this mission:

> We call for fire with the Ravens and Pumas regularly. … We've done multiple exercises with the mortars organic to the company and artillery. Both have been used and we've adjusted fire off both of them.

At the same time, our interactions with artillery units—units who would be an obvious beneficiary of SUAS-enabled rapid target engagement—suggested less consistent usage. When contacted, some artillery units claimed that they did not use SUAS in any capacity at all. Others discussed using SUAS only for situational awareness. A division SUAS program manager observed:

> Artillery units don't use it as much as you'd think. I was surprised that they don't use them more. For targeting, [battle damage assessment], from division perspective [this would be useful] especially during exercises.

There were even fewer mentions of persistent EW (four mentions in four interviews) and persistent C4 (three mentions in three interviews) by SUAS users. As a whole, interviewee responses indicate that experience across the five mission profiles is uneven. Situational awareness and force protection uses are understood, rapid target engagement uses are somewhat understood, while other mission profiles are far less so.

This is not to say that all OccFlds require the same level of proficiency across all the SUAS mission profiles. From interview responses and the literature review, we formed a hypothesis that different communities have varying needs for these mission profiles. Our research shows that the infantry community has a clear need for all five mission profiles, but it is not yet clear which mission profiles are crucial for others. Figure 3 provides our current assessment of which mission profiles might be required for each community.

Potential requirement

	Situational awareness	Force protection	Rapid target engagement	Persistent C4	Persistent EW
Infantry	x	x	x	?	?
ANGLICO	x		x	?	
Artillery	?	?	x		
Communications	?	?		?	
LAR	x	x	x		
Armor	x	?			
Combat engineer	x			?	
Intelligence	?	?			
Law enforcement	?	?			
SIGINT	?	?			
Reconnaissance	?	?			
AAV	?				

Command element unit x = demonstrated ability ? = RAND assessed need

Figure 3. RAND-Assessed Potential Mission Demand by Unit Type

Note. Source: RAND analysis

We believe the Marine Corps should consider identifying each OccFld/unit's true demand for each mission profile. This will be a crucial task that will shape requirements across the doctrine, organization, training, materiel, leadership and education, personnel, and facilities (DOTMLPF) and help the Marine Corps take the fullest advantage of SUAS at the least risk of making a poor investment decision.

Access Is Key to Further Understanding of SUAS Utility

We found that the infantry and LAR communities had the most mature understanding of SUAS. For the infantry, this is because it has been given priority in accessing platforms. A MEF SUAS program manager (PM) illustrated this:

> So what I base everything off of is the [SUAS] fielding plan, so we're keeping that going as a good place to start. It's a good baseline, but the problem is there are so many other units and there's not enough inventory to go across the spectrum. … For example, units A and B went out the door with almost three times the systems because their [concept of operation] was briefed to Commandant [of the Marine Corps]. [We] have to balance

> the small number of systems across the [MEF]. If you don't have anything going on, I'll probably take your systems.

Because the infantry has such extensive exposure to the platforms, the infantry had the opportunity to develop and refine CONEMPs for situational awareness, force protection, and (to a lesser extent) rapid target engagement. We also observed that the infantry has started to consider the potential utility of SUAS for providing persistent C4 and EW.

The LAR community gained its understanding of SUAS differently. Rather than gaining exposure through prolonged access to existing platforms alone, some of its units also have direct access to the Marine Corps Warfighting Lab (MCWL), the Office of Naval Research (ONR), and through them, SUAS contractor teams. Through those organizations, the LAR community has been able to focus directly on experimenting with CONEMPs and with different platforms instead of learning through exposure alone. Because of this different form of access and the relatively small size of the LAR community, it has achieved a level of SUAS maturity that is comparable to that of the infantry. However, we do not believe the LAR community approach is scalable because direct relationships with the MCWL and ONR can only be sustained for a small number of units.

The other communities had lower levels of experience using the platforms in training and during deployment. Interview responses and AAR reviews suggest that most communities have had some access to SUAS, but such access has not been consistent. In some cases, units were not aware they had access to the platforms, despite the fact that such platforms were on their unit tables of equipment (T/Es). We believe the way that the Marine Corps has prioritized SUAS access over time has suppressed demand from low-priority units. In other words, these units have learned to stop requesting SUAS. One battalion commander's observation highlights an extreme case:

> I was six months into job before I knew we had designated [RQ-20B] Pumas. It was just a drive by conversation. I saw sheet of paper. There is education gap between what [HQMC and higher echelons] produce and the information they disseminate to units. Some units still don't know they have airframes designated for them up there.

When units do gain access to SUAS, they often must focus on maintaining operator currency on the platforms—activities that contribute little to a unit's ability to employ SUAS as described in the mission profiles or to support any other unit task. One SUAS PM from a low-priority unit observed that maintaining operator currency (discussed more later) is his key concern.

> The main thing with SUAS is that they need to be more available. So currency prevents them from being used because it's impossible to be current. I would like to use them more, but it takes a [lot] of work to be current.

As a result of uneven access, units across the CE and GCE have uneven experience employing SUAS. Units that have sufficient access to SUAS have room to experiment with CONEMPs, gain experience with SUAS, and determine the true demand for SUAS. Units that have little access are only able to sustain basic operator skills to maintain currency. We also observed differences in SUAS experience across different units of the same community. This was particularly evident in our interactions with the artillery community. Consistent access drives understanding of how SUAS and SUAS mission profiles contribute to a community.

Non-Material Issues Must Also Be Addressed to Increase Access

We also found that significant impediments to greater SUAS maturity in the Marine Corps are not related to material solutions. Although our protocols focused mainly on material topics, a consistent trend in user interviews was a focus on non-material issues. The most cited issues were doctrinal, personnel, and training, each of which is described next. Although non-material aspects of SUAS employment were out of the scope of this research, the issues described next are relevant to the issue of SUAS access previously discussed. Further research should be conducted into the full range of DOTMLPF issues impacting the use of SUAS by CE and GCE units and how they might be addressed.

Lack of Agreed-Upon SUAS Doctrine and Concepts Impedes Tactical-Level Usage

The Marine Corps today lacks SUAS doctrine and concepts of employment for CE and GCE units. Some service-wide guidance has been articulated, but such guidance is insufficiently detailed. Guidance includes a reference publication on unmanned aircraft systems (MCRP 3-20.5, *Unmanned Aircraft System Operations*) and the SUAS training and readiness (T&R) manual (NAVMC 3500.107). MCRP 3-20.5 contains useful employment information and considerations but is meant primarily for Group 3 platforms employed by dedicated unmanned aircraft squadrons. The T&R manual provides standards for training Group 1 operators, but it offers nothing on employing SUAS operationally.

The lack of generally understood doctrine, CONEMPs, and other service-wide direction impedes the general utility of SUAS. We observed from our interviews that many units can conceptualize the situational awareness and, to lesser degrees, force protection and rapid target engagement profiles without doctrine or other guidance. However, few interviewees could imagine the utility of SUAS for persistent C4 and persistent EW. Without a basic understanding of these profiles, units cannot determine the true need for SUAS in their units. Furthermore, the lack of doctrine or other guidance impedes consistent understanding of the required training and support needed to allow units to fully use SUAS.

Personnel Management Is Inefficient and Can Affect SUAS Operations

Another issue that impedes SUAS maturity across the CE and GCE is the uneven availability of qualified operators. SUAS training is not centrally tracked in the Marine Corps, thus making it difficult to manage the Marine Corps' inventory of trained operators. This can make it difficult for a unit to ensure that it has enough current, qualified operators to support its mission. For example, several units reported difficulty in maintaining visibility into its SUAS operators' currency. Units also lose SUAS operators due to normal personnel rotations and are sometimes unable to secure other training opportunities in time to support a deployment.[13] This concern is exacerbated by the TALSAs' relatively limited training capacity and the relatively small number of operators already trained; rectifying a training shortage within a reasonable timeframe may not be feasible for some units. Finally, the need for effective SUAS personnel management will only grow as the Marine Corps reorganizes itself to more fully integrate SUAS and other technologies into its operations.

Training

We observed two training-related issues that negatively impact SUAS maturity across the CE and GCE. First, formal SUAS training (provided by the TALSAs) is focused

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[13] User interview

on system basics and does not provide instruction on how to employ SUAS operationally. The remarks of one unit's SUAS program manager are typical:

> My lance corporal had good enough training to operate, but he lacked the tactical aspect. Our biggest problem with SUAS is a massive gap between learning how to fly it and then how to use it tactically. The lance corporal gets to fly for half an hour one time a month. I'm here to bridge the gap and teach him how to find things through a sensor. What we don't have is some type of institution that will standardize this training and bring lance corporals from being able to operate it, [to] fly[ing] it tactically.

Second, current training areas may be insufficient to support all SUAS mission profiles. One of the biggest limiting factors is access to ranges where units can fly SUAS. Range control regulations at some bases limit units' abilities to train effectively. For instance, Camp Lejeune–based units are not allowed to conduct SUAS handoffs without both pilots having visual contact with the platform.[14] Also, units are not allowed to operate from a moving platform (e.g., HMMWV, LAV, etc.), although doing so is critical to exploiting SUAS in an operational environment. Current range restrictions may require units to spend extra time and resources to get exceptions, or such restrictions may not be waived at all. This prevents units from incorporating SUAS more fully into individual and collective training.

Three Procurement and Allocation Models Address the Access Need to Varying Degrees

From our mathematical matching and quantity identification process, we articulated two different allocation models based on different parameters we identified as essential and compared them to the Marine Corps' status quo model. These alternatives helped us demonstrate what factors were drivers of cost and capability for investment in SUAS technology. The three models were

- a **status quo** model that is based heavily on current Marine Corps procurement strategies
- an **economy buy** model based on the full buy option that economizes by reducing access (and thus, total platform quantities) to platforms during some periods of a unit's deployment cycle
- a **full buy** model developed from our analysis that meets all identified strategic procurement and allocation goals

Representative unit costs were used for all models and are shown in Table 3. Recommendations are shown in Table 4.

Table 3. Representative Unit Costs

EOTACS category	Example Platform	Representative Unit Cost
2 (Nano/VTOL)	PD-100	$51,000
3 (Micro/VTOL)	Instant Eye	$18,000
4 (SR/SE VTOL)	SkyRanger	$200,000
5 (SR/SE FW)	Wasp, Raven	$293,500*
6 (MR/ME FW)	Puma	$267,000
7 (LR/LE FW)	Stalker XE	$1,547,770

[14]User interview

Note. *Cost figure is an average of Raven and Wasp unit costs
** Only direct material costs for example platforms are shown here. Costs are meant to be strictly representative; decision-making based on these costs should consider updated cost information or assumptions.
Source: RAND and HQMC(CD&I) analysis

Table 4. Representative CE and GCE SUAS Procurement and Allocation Recommendations to FY2025 by Occupational Field

	Status Quo		Economy Buy		Full Buy	
	Quantity*	**Cost ($m)**	**Quantity***	**Cost ($m)**	**Quantity***	**Cost ($m)**
Infantry	1,676	160	2,434	274	2,634	289
ANGLICO	30	8	12	11	36	31
Artillery	30	8	63	45	108	65
Communications	0	0	17	5	21	6
LAR	20	6	282	86	322	96
Armor	19	5	29	45	42	65
Combat engineer	26	7	85	17	129	26
Intelligence	7	2	9	2	12	2
Law enforcement	0	0	26	5	39	8
SIGINT	6	2	3	5	6	9
Reconnaissance	26	7	159	6	237	9
AAV	0	0	23	6	33	9
Total	**1,840**	**205**	**3,142**	**506**	**3,619**	**616**

Note. * Combined total of all Category 2-7 platforms
Source: RAND and HQMC(CD&I) analysis

Status Quo

The status quo option was developed by HQMC(CD&I) prior to this research. This option expands the current SUAS inventory somewhat; it mainly procures more RQ-20B Puma platforms in response to some unit-level inputs but does not take the divestiture of Category 5 (SR/SE fixed wing) RQ-12A Wasp and RQ-11B Raven platforms into account. It preserves the current focus on infantry units. No Category 7 (LR/LE fixed wing) platforms are identified. No platforms are identified for assault amphibian, law enforcement, or communications units. It represents 50% of the full buy quantity developed from this analysis.

Economy Buy

The economy buy option provides similar expected platform availability to all OccFlds and echelons as the full buy option, but at reduced cost. In this option, active component infantry and light armored reconnaissance (LAR) units manage their SUAS inventories organically. Centralized training and logistics support agencies (TALSAs) continue to manage non-infantry and LAR unit inventories. Quantities are reduced to two-thirds of the full buy to account for typical force generation for typical unit deployment rotations; this makes platforms available to units undergoing pre-deployment training and deployment cycles, but not during their post-deployment recovery phase.[15] This cut 732 platforms across all categories from the full buy option and saves $78.25 million in direct material costs.

Full Buy

The full buy option fulfills our predicted demand and procures enough platforms to ensure availability for all units at any stage of the unit's training and deployment cycle. TALSAs continue to manage non-infantry and LAR unit inventories.

Findings and Recommendations

The Marine Corps has made significant advances in developing its SUAS proficiency since 2015, when its current goals were articulated. Still, there is more potential in SUAS that the Marine Corps has not fully exploited. Separately, SUAS technology is advancing to meet commercial, as well as military, needs. This is an unusual confluence of circumstances that DoD and Marine Corps force development processes were not designed to accommodate. In that light, we offer the following recommendations to best leverage this emerging technology:

- *Invest significantly more (on the order of $500 million) over the next five to six years to redouble experimentation and conceptual development efforts.* We recommend an investment strategy that prioritizes procurement of capabilities for infantry and LAR communities to help them further integrate SUAS into their operations and allows all other CE and GCE communities to explore the full range of utility that SUAS may provide. To enable that effort, procurement approaches should balance three elements: maximizing capability, minimizing technological regret, and minimizing cost.
- *Conduct further analysis into demand and usage to enable tailored procurement approaches.* Further analysis is required of each of OccFld's true demands for SUAS in each of five identified mission profiles. Additionally, the Marine Corps should facilitate the collection of more precise usage data, and analysis of SUAS market dynamics are needed to support SUAS investment decisions that can keep up with the technology's fast development pace.
- *Research full range of DOTMLPF issues.* Our analysis found that significant impediments to greater SUAS maturity in the Marine Corps are not related to material solutions. Further analysis of DOTMLPF considerations is required. We recommend that the Marine Corps review and refine its SUAS doctrine, manpower management, and training to fully cement operational insights and best practices already found.

SUAS technology has significant potential to contribute to the force described in the Marine Operating Concept. However, this technology's fast development unrelated to U.S. military needs demands a force development approach that relies heavily on fast iterative operational experimentation and conceptual development. Our assessment of previous

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[15] This assumption is derived from typical deployment cycles and global force management processes; this ratio can be changed depending on substantive changes to these guiding principles. This economization was inspired by the example of MEU explosive ordnance disposal (EOD) equipment set sharing practices; only enough equipment is procured to outfit units training for deployment and currently deployed, but not those recovering from deployment.

Marine Corps SUAS investment decisions indicates that they were mindful of this; our recommendations provide a means to continue that approach as the Marine Corps scales up its SUAS investments.

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