Operationalizing Modelling and Simulations for Drone Swarm Employment In a C2 Challenged Environment

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ABSTRACT

As Modelling and Simulations (M&S) capabilities have matured they have failed to bolster operational capabilities, specifically regarding the ability to provide technological advantages in drone warfare. The M&S capabilities to import and intuitively generate terrain based on multi-spectrum geospatial intelligence, individual AI, and collective AI present opportunities within the current challenges of integrating drone swarms in a communications and GPS challenged environment. M&S provides the ability to Command and Control (C2) a drone swarm through a small team of controllers including tactical employment in the offense and defense as well as kill chain approval for multiple drones. Because the output display information and High-Level Architecture (HLA) broadcast languages are the common Input/Output (IO) stream of these simulations, this is the point at which common interfaces can provide for sensor input and control outputs to rapidly integrate emerging drone technology. Additionally, the ability to convert the live environment to a virtual/constructive simulation creates a temporary GPS network that is less susceptible to adversary interference. These advancements to the information technology infrastructure coupled with advances in drone logistical capabilities, counter drone munitions, and machine learning for development of tactics allow from a seamless transition from M&S based training to a Live, Virtual, and Constructive combat environment.

Keywords: modelling & simulations, drone swarm, geospatial intelligence

1.0 THE LIMITED APPLICATION OF MODELLING AND SIMULATIONS

M&S have shown to be highly effective in many aspects of military training and education. This has been bolstered by advancements in modelling that increases the realism of training. Coupled with the ability to incorporate different systems through federation, the ability to replicate live decision-making requirements at the highest levels has also improved. The incorporation of data tracking for logistics and determining effectiveness based on complex analysis further allows the understanding of the impact of integrating modelling and simulations in military training while also presenting the opportunity for use beyond traditional M&S training [3], [8].

Military simulations for individual tasks have shown to be most effective when they are high fidelity and/or tactile [3]. Simulations for decision making may have some requirement for visualizing the data, but are more data driven. This is because although the data provided by the simulation must always reflect the live environment to the highest degree of accuracy [8], the information provided to the training audience changes with how the trainees are expected to observe, interact with, and react to the data [4].

Interoperability has also been a positive advancement in military simulations [11]. While persistent and

distributed federation is not fully operational, it is possible and has shown to be feasible in demonstrations and short-term training events [5], [6]. Personal observation has shown that persistent and distributed federation is not a technical shortfall but lack of funding due to low perceived value. Conversely, although standardization of models is the purpose of STANAG 4603 it has not achieved its goal because it can be more time and labor intensive to resolve inconsistencies by registering new models [5].

The advancements in HLA have provided a valuable efficiency for the exchange of information [11], [13]. Further adherence to standardization will continue this advancement as the underlying data packets and overall data table become less dense and rely upon locally held specifications [6]. The standardization of terrain to World Geodetic System 1984 (WGS84) provides opportunities for other efficiencies in terrain generation, georectification, and cross functional area software interoperability.

Combat drones have similar requirements to models as far as the inputs required to control their actions and visually render the battlespace. Unlike humans who interact with the battlespace using their senses, primarily visual, drones interact with the data that defines the battlespace. Gains in accuracy, efficiency, interoperability, and standardization with respect to M&S have equal applicability and value in the operational environment [7] when applied to drone warfare. Table 1-1 shows the similarities between drones and models in the digital environment as well as the human induced C2 requirements.

Table 1-1: Comparison of M&S and Drone Warfare C2 Requirements

C2 Requirements	M&S Training	Drone Warfare
Data Form	SQL Database	SQL Database
Visualization	Graphics Card Rendered	Full Motion Video Feed
Visualization Audience	Human	Human
Tactics Selection (Friendly)	Human	Human
Tactics Selection (Adversary)	Human or AI	Human
Command Authority	Human	Human
Geolocation	WGS84 (Absolute Anchor)	WGS84 (Satellite Derived)
Terminal Guidance	AI via Entity Exchange	Human

From this table some considerations can start to form for evaluation. The common data form, SQL databases, allows for rapid exchange of AI, entity/adversary target data exchange, and measuring effectiveness through analysis of fuzzy data [14] while avoiding and correcting inconsistencies [8], [11]. Geolocation has the same potential with respect to how the digital map is anchored in the physical terrain. The places where humans appear is also important because target discretion is required by the Laws of Armed Conflict (LOAC) and C2 requires situational awareness but places a higher demand on communications bandwidth.

Figure 1-1 depicts the current concept of employment of drones in the battlespace. Each drone acts as an extension of a controller or team of controllers. Drones must continuously access and update WGS84 data for navigation and reference for humans or other drones in the battlespace. Additionally, the drone acts as an

extension of human observers as a passive entity. Intelligence analysis does involve AI augmentation, but not during the observation phase. Instead, this is done during the interpretation phase using Measurement and Signature Intelligence (MASINT) analysis controlled by a human and leading to delays [2], [13]. The shared SQL databases are then populated for multi-discipline fusion at a later stage by a human.

Figure 1-1: Drones as an Extension of the Warfighter

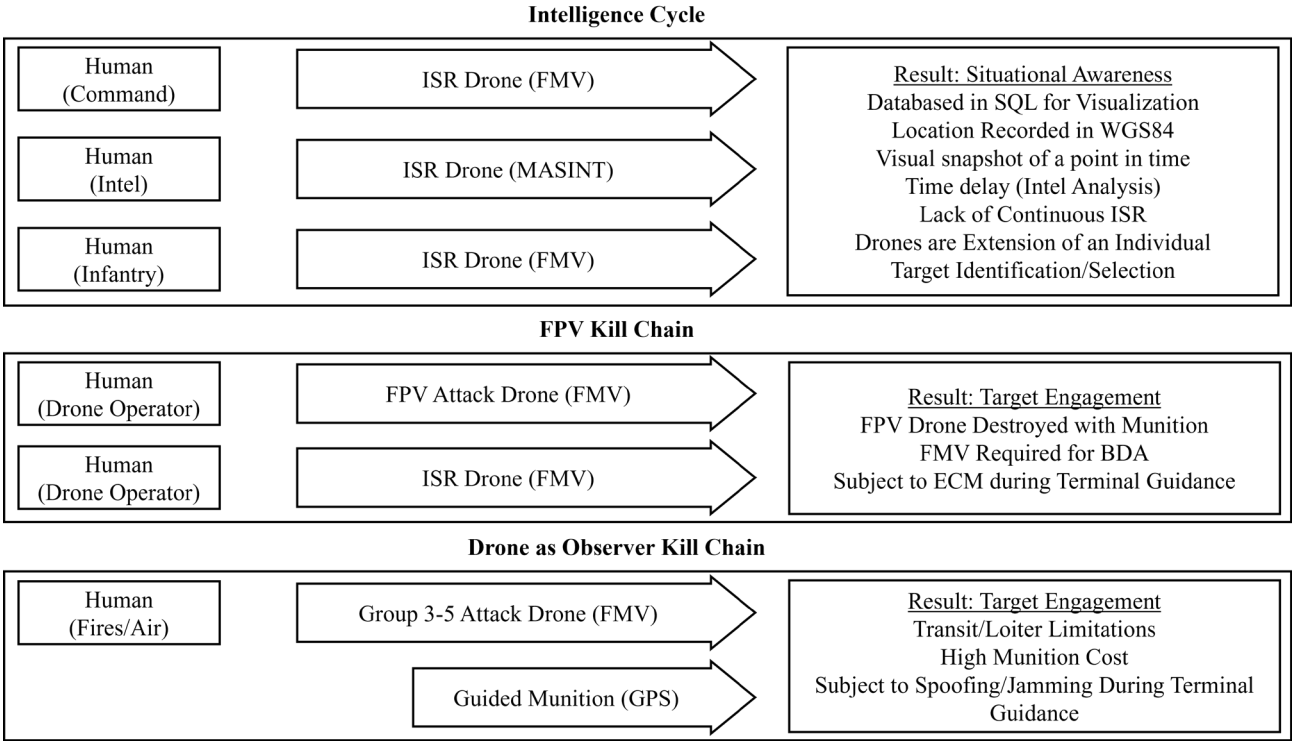
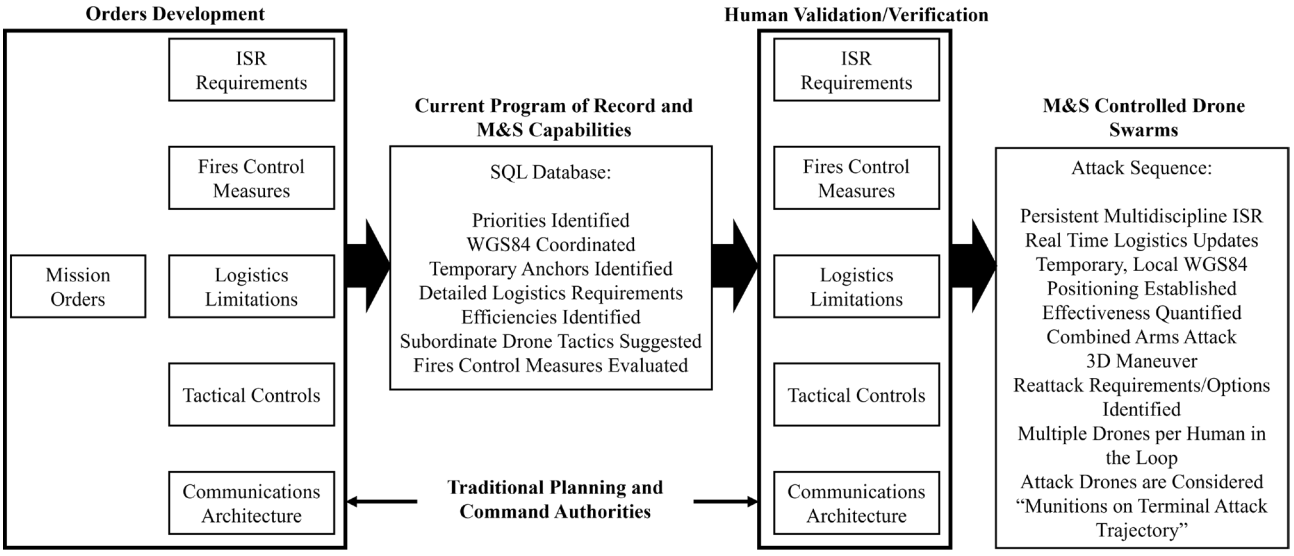


Figure 1-2 depicts the use of the existing Application Program Interfaces (APIs) and algorithms to augment human assessments. The challenges and advantages of this proposed integration of M&S as a drone control mechanism are discussed as the scope of this research. These assessments are based upon personal combat experience, technical demonstrations from industry, open-source reporting on current drone usage, and academic research.

Figure 1-2: Drones as a Force Multiplier



2.0 CHALLENGES IN DRONE WARFARE

The two problems to be addressed are the lack of integration of M&S in operational capacity [3] and the opportunities to integrate with hardware to achieve drone swarm tactics using current technologies. While the previous section focused on M&S, this section will focus on identifying challenges in current drone warfare. The following section will present the M&S based opportunities to address these problems.

Open-source research suggests that capabilities are present in Ukraine that are decreasing the effectiveness of GPS guided munitions and FPV drones. The most likely capabilities to produce these effects are GPS spoofing/jamming and Electronic Countermeasures (ECM). These capabilities must be considered in their effects on drone swarms including accuracy of conventional munitions and interrupting FMV feeds on FPV drones.

These battlespace effects also affect the C2 requirements within the battlespace and when the drone must transition from a delivery method to a munition on terminal attack trajectory. This is the point when the drone must be treated with the same regard as a guided munition and no longer under direct control of the individual. A past example of this advancement is the conversion of the AGM-65 Maverick guided missile from TV Guidance to other forms of MASINT. This allows the guidance system to use sensory mechanisms other than the visible spectrum to hit its target and increases accuracy with the computer reacting faster than a human.

Another problem that is directly reflective of a M&S limitation is the manpower requirements [3], [4]. C2 of the drone system as currently employed is a minimum of one human per drone. Current AI models achieve maneuver by escalating to a different API when moving through individual and collective tasks [4], [7], [8]. In human terms, the individual API of move to cover and return fire is overridden by unit maneuver and would move through the battlespace with a total lack of self-preservation. This concept is the essential barrier to achieving drone swarms.

Current development and acquisition of drone technology has the same compatibility issues demonstrated by the

process of integrating proprietary simulations and federating between HLA and DIS based simulations [6], [11]. Just as enumerations challenge the ability to integrate in a persistent manner, a level of standardization in drone technology has not been achieved [5]. To solve the logistical challenges and shorten supply lines, a solution must address standardization of hardware at the closest point to the battlespace. This includes the communications interface to the drone C2 systems with respect to hardware but also includes the mechanical components of a drone that are not able to be produces through advanced manufacturing. These mechanical components, however, lie outside the scope of this research.

The ability to develop tactics, techniques, and procedures (TTPs) rapidly has also been problematic in current drone warfare. TTPs are based upon the employment of the drone as an ISR platform, cost effective munitions delivery platform, or persistent munition. All these uses fail to realize the capabilities needed for some level of autonomy within the drone fleet to achieve synergy.

Another critical failure in drone warfare is to develop TTPs for drones in the defense and counter-drone measures. While selecting appropriate detection methods is outside the scope of this research, munitions development and testing as well as doctrine development will be addressed. Human forces and drones alike must have a defensive capability against adversary drones but there should also be consideration for effective drone on drone engagement.

3.0 LEVERAGING M&S TO ENHANCE DRONE AND COUNTER-DRONE OPERATIONS

This section attempts to leverage existing technologies where available to remedy the challenges of current drone employment. The purpose of leveraging existing technologies is to respect the limitations of the military industrial complex to adopt and adapt to a new strategic use of drones. The next section will then discuss means, methods, and priorities for production to maintain coherency and compatibility.

3.1 M&S For Geolocation in a GPS Challenged Environment

Geolocation is the primary focus in traversing the battlespace, target identification/confirmation, and terminal guidance of conventional munitions. Because these rely heavily upon GPS to penetrate conventional countermeasures such as smoke and flares, the adversary ability to broadcast a stronger land-based signal to interfere with the satellite signal must be addressed. Land drones, military aircraft, UAVs, and land-based emitters outside the area of effect or inserted prior to adversary introduction of countermeasures can provide a temporary, local GPS capability.

Because M&S and GPS systems rely on WGS84 data, the interoperability already exists with the consistency of data set masking and manipulation. The APIs also exist to import and export between M&S systems and SQL databases that underly PoR systems and Augmented Reality (AR) tools [10]. This is to state that M&S also have the ability to interact with the underlying SQL database [2] which will be described in more detail later. This additionally means that conventional munitions could receive assistance in terminal guidance from the temporary, local GPS system just as the bunker buster was the counter to enemy fortifications in the caves of Afghanistan.

3.2 M&S For Terminal Guidance in an ECM Rich Environment

Terminal Guidance as discussed in this section must initiate from a human source while the drone is outside of

the effects of adversary ECM. By employing the temporary, local GPS the drone can use sensors such as Light Detection and Ranging (Lidar), radar, ultrasonic, and Electro-optical Infrared to update the absolute location of the target in locally stored maps. Minimizing the amount of map data and communications requirements allows for smaller electronics packages while increasing accuracy. It does, however, necessitate adaptation to not having any ability for humans to observe the attack in at least some instances.

The effect is that the individual drones can provide real time updates and increased fidelity in the battlespace [2], [8]. Upon attack approval, the drone would download the most up-to-date map chip including the position of the target and any changes such as destroyed vehicles, downed trees, and impact craters resulting from battle [8]. Using local sensors, the attack drone can determine position, direction of travel, and weaknesses for update in the local map. Using this process, the interface with sensors becomes the needed advancement instead of installation of complex, proprietary, and limited guidance packages from conventional munitions.

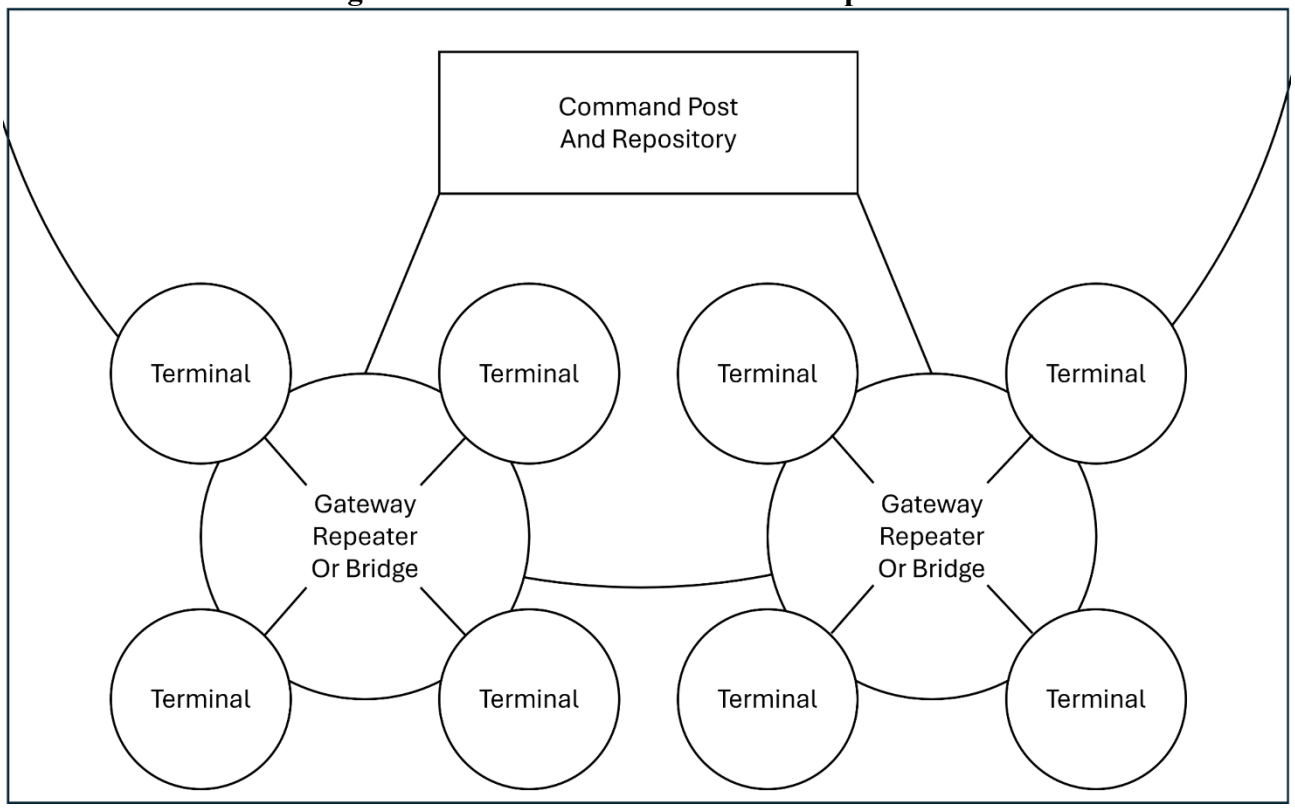
This terminal guidance concept means they will be most adept for offensive actions but with some consideration can act in the defense, urban areas, or any place timely target discretion is required. While this will slow the kill chain, increase the number of communications drones/anchors, and increase demand for human input it is required by and consistent with the LOAC. Identify Friend or Foe (IFF) would also be a consideration that can adapt blockchain verification as a challenge and pass. The use of blockchain in this aspect also provides a unique key for encryption and decryption of secure communications protocols [1], [12].

Using existing technologies, blockchain used in connection with laser target designators can interface with legacy guidance systems as well as provide for multiple target designation from a platform if the temporary local GPS is compromised. Unaffected air platforms or ground-based units with absolute locations can continue to designate targets for attack drones with specificity and discretion in an ECM rich and GPS restricted environment. Using legacy technology, current capabilities, and M&S based entity control, the adversary has a greater negative effect on their own forces by contesting the EMR domain than on the drone swarm.

3.3 M&S For Redundant and Distributed C2

The communications architecture for this research is based upon creation of a persistent and distributed federation of simulations [11]. This concept centralizes data management, interpretation, and visualization while providing distributed command and control capabilities and redundancy. Figure 3-1 presents the M&S concept of distributed and federated simulations. In the lowest levels, DIS broadcast is the most effective way to ensure consistency [6]. The hub acts as the repository with capability to translate the DIS information for HLA database management [6] with other hubs and the main repository located outside adversary reach.

Figure 3-1: Persistent Federated Concept of M&S



Because the control software is based in modelling and simulations with the addition of blockchain for encryption [1], [12], this model is appropriate for drone C2. Sharding allows hubs to operate on lower bandwidth while still employing blockchain encryption [12]. Terminals exchange detailed information from sensors but require no rendering or FMV feedback in most cases lowering bandwidth demands [13]. As depicted, it also has multiple forms of redundancy. This provides the most battlespace detail within the defined WGS84 based map chip. It also has the ability to flatten terrain by removing entities and incorporating them into the terrain when they are confirmed destroyed and stationary.

This architecture also allows the hub to keep pertinent detailed data on battle damage, logistics data, and other details of the battlespace while isolating the HLA data requirements. This serves to reduce the fidelity of the tactical level DIS data by aggregating units to be displayed on operational level C2 PoR or adapted simulation [6]. Hubs only push required data or priority requirements while maintaining large amounts of data for headquarters pull or detailed analysis when time and bandwidth permit.

Hubs communicate with higher level servers as well as adjacent hubs to ensure the greatest level of redundancy to physical attack and a contested EMR domain [11]. This approach ensures autonomy is retained by the individual drones as will be discussed in the next section while ensuring full dissemination of commands from higher systems [7]. This also allows humans a conducive environment to control drones as late as possible in the kill chain to reduce the likelihood of friendly fire or collateral damage through robust and redundant communications using existing technology.

3.4 Leveraging Layered Artificial Intelligence For Single Operator/Multiple Drone Control

As discussed earlier, AI as used in simulations tends to override the individual AI that provides for survivability and coherency [7], [8]. In M&S, this creates unrealistic movements through adversary fire as well resulting in loss of participant buy-in but also increases the death rate of NPCs [4], [8]. AI can be viewed to have the same challenges of aggregation/disaggregation presented in HLA/DIS federation [6].

Whereas DIS can be aggregated and simplified to HLA readily, it is difficult to disaggregate from HLA to DIS [6]. Combat AI can be understood to build from individual tasks to complex tasks [7], [8] in alignment with current military training and education principles. These tasks are aggregated or aligned through effective communication and interpretation of orders from higher commands.

For example, a battalion commander passes down an order and each company commander interprets their piece of the battlespace and required tasks. They then select their tactics, get battalion approval, and then issue the company order to the platoons. This continues through the platoon, section, and fireteam until it reaches the four individuals that comprise the fireteam. While never denying or disregarding orders, the individuals maintain their propensity toward mission accomplishment and survivability. The balance of priority in mission accomplishment and survivability is the criticality and relational timetable of tactical operations in the operational and strategic plan.

For this reason, each individual drone must execute its own level of AI to accomplish the collective tasks [7]. The application of machine learning which I will discuss later allows the re-development of AI from individual level through all levels of drone unit command. Commands are passed down through secure communications using blockchain for encryption and sharding within hubs [12]. The drones then use their local APIs to select attack geometries and 3D fix and flank tactics.

After verifying their plan with higher orders, they then communicate with adjacent hubs as well as issuing commands to subordinate hubs. This continues through the chain until the kill chain is approved by a human. At this point the attack drones either release their munitions or become munitions on final attack trajectory. They are committed to detonate just as conventional munition are and must be regarded as such. A current example of cooperation is found in the BLU-108 and the conversion from delivery method to munition is seen in loiter munitions.

3.5 M&S For Supply Chain and Production Management

As one-way attack drones are expended or other drones are neutralized, M&S already has the logistics tracking ability to record and disseminate this information. Immediate needs for prolonged combat operations can be fed back to the forward production facility discussed in the next section. On a larger scale, this provides refinement on operations effectiveness through analysis of fuzzy data sets [14] allowing for efficient overall supply chain management.

3.6 Leveraging Machine Learning For Rapid Development and Battlefield Response

As discussed in the previous section, logistics lines are shorter and more efficient when applying current SQL databasing and AI in M&S. By interfacing with the forward production facilities, drones consisting of standardized munitions, motors, sensors, and controller boards are installed in a drone's chassis produced through additive manufacturing. This reduces the stockpiles of proprietary parts or completed drones needed to sustain pressure on adversary units. By standardizing the control boards and chipset, chips may be pre-

programmed for certain chassis or reprogrammed as the need for specific platforms arises.

Another factor of rapid battlefield response is to react to unexpected or unknown adversary maneuver or defensive capabilities. Additional armor, camouflage, or other masking techniques in addition to the change in terrain from the effects of battle may be rectified through AI [2], [13]. Terrain changes may be noted by simulation, or they may require human interaction through geospatial or imagery intelligence professionals [2], [8], [13]. The same can be said when a target cannot be discerned because of masking.

Conversely, the addition of fuzzy data analysis to current M&S databasing [14] can discretely identify attack trajectories, critical attack points, required re-attack targets, or multiple drone requirements to fix a target for attack [5], [6], [7]. This increases battlefield effectiveness that outpaces the adversary's ability to respond. When coupled with the ability to rapidly discern and disseminate changes to the physical environment that affect maneuver, this provides significant battlefield advantage while always maintaining human control of critical decisions.

3.7 M&S Efficiency Applied to Defensive Operations

While the ability to detect adversary drones has been demonstrated, they still have shortfalls. The first is that they rely too heavily on human observation or FMV to target and engage the adversary drone. Using the same target identification principles discussed for conventional targets, the detection system can identify the adversary position in the temporary, local GPS provided by M&S. This position can then be identified by MASINT or FMV as dictated by the environment and friendly posture. Defensive drones can then engage adversary drones. AR provides the opportunity to display engagement data for humans [10] in both offensive and defensive operations.

Human identified threats can be entered in the same NATO standard combat reports for drone engagement as well. Although sensors can more readily pinpoint the adversary position in the simulation database, using direction, approximate distance, and movement to identify potential adversary positions is readily accomplished through the same AI and sensors already discussed. Drones can then be used in the defense including counter-drone operations.

This moves to the second challenge which is the weapon system for engagement. While high recoil systems such as gun type weapons provide multiple shots, they are not suitable to be mounted on drones due to the recoil. They can be integrated in ground-based defenses and utilized by M&S to engage adversary entities. M&S provides the ability to map the engagement area with respect to weapon capabilities to provide for interlocking fields of fire and the best use of the engagement areas to maintain standoff [9].

Other weapon systems such as the AT-4 recoilless rifle have been mounted to drones. These weapon systems as configured and demonstrated only allow the drone two unguided attacks per platform. The fact the warhead could be drone mounted as a one-way attack drone with increased accuracy means that unless the drone can reach an accuracy of above 50% consistently, it is more efficient to move to a one-way attack drone in this application. Accurately modelling the weapon and adversary allows M&S to use either AI or human guided repetitive testing to develop TTPs and ensure efficiency.

ECM and entanglement devices have shown to be the most effective defensive devices. ECM effect areas can be mapped in M&S [6], [11] for offensive and defensive operations [9]. Likewise, World War II vertical wires and balloons can be mapped and are rendered less effective. Using ECM to block adversary FPV and FMV provides secrecy for defensive operations during attack as the adversary drone will lose these feeds and be destroyed by

defensive munitions whose origins will be unknown.

MASINT ISR platforms can locally record defensive preparations [13] and after leaving the ECM effects can upload changes in defensive posture. While this is advantageous for friendly offensive operations, it presents the requirement to pursue or destroy adversary ISR platforms within the ECM areas. This is where entanglement munitions such as high tensile fibers in a chaff cartridge can be employed from drone based, ground based, static, or human fired weapons. Laser designation or local sensor guided attack drones can also operate within the friendly ECM effect area to destroy adversary targets both drone and conventional.

All weapons must be procured with the requirement for accurate models of range, accuracy, ballistics, and overall effectiveness are required for M&S to properly integrate these systems. M&S can then provide for drone and counter-drone operations in the defense. When augmented by human controlled drones, weapons, and human refinement of AI estimates, this provides a significant advantage in the defense even if the adversary develops like capabilities [9].

4.0 DEVELOPMENT PRIORITIES

This section discussed the advancement process of the previously listed technologies. In a production timeline, it would be ineffective to build TTPs when models are inconsistent or inaccurate. By understanding the multiple development lines and when they affect one another, the process is optimized to reach full operational capability.

4.1 Standardized, Highly Accurate Models

Creating a database of detailed, accurate models is the first task. Many models already exist but multiple depictions of an entity create inconsistencies in characteristics and parametric data or duplicate enumerations [5], [6]. These are problematic to persistence and performance of the AI when merging M&S with real world entities. This applies to the entities as well as weapons capabilities.

4.2 Sensor Replication in the Virtual Environment

Part of the accuracy in models that must be a focus and should be tested for accurate parametric are the sensor capabilities. This is a two-part problem and while AI can provide accurate estimates, the greatest accuracy is achieved through real world testing. This is based upon the capabilities of the sensor that must be accurately mapped, but also the abilities of entities to mask their signature [6]. MASINT is a critical component of operationalizing M&S and using AR there are additional methods to interact with the data [10].

This can be developed concurrently with the efforts to adapt technology for the temporary, local GPS. Because simulations can readily import WGS84 data, this is focused on the anchor technology. After that step, the ability to update terrain in real time with respect to battlespace effects or improved accuracy [8] can be developed.

4.3 Layered Artificial Intelligence

Concurrently with model refinement, the APIs that will provide for machine learning can be developed [6]. These APIs should be operational with respect to human controlled, one on one combat for the first development phase. The second phase of development is the ability to decipher the fuzzy data to categorize and evaluate effectiveness of certain tactics [14]. The third phase is to passive allow AI controlled one on one interactions to

confirm assessments of effectiveness or refine estimates [7].

The next step in development is two create team tactics. This is first done in pairs and then with increasing unit size. Different combinations of human and AI controlled entities provides the best data to be analyzed for analysis before moving to the next larger unit size [7]. The layered AI then provides a way for the system to disaggregate actions from centralized orders while also allowing aggregation of hub data [8]. The ability to aggregate hub data is directly linked to the ability to create a stable and persistent HLA/DIS federation.

4.4 Counter-Drone Sensor Integration

Counter drone sensors must also be developed, accurately modelled, and integrated to the simulations environment prior to developed counter drone AI. Accurate area of effect and masking should be tested real world to ensure parametric accuracy. These sensors must through simulation the same way as drone entities to develop effective TTPs but require some level of accurate drone individual and collective AI for testing.

4.5 Counter-Drone Weapons Development and Modelling

Low recoil, multi shot munitions can also be entered into development early in the process. Accurately modelled munitions and weapons can be entered into testing alongside conventional weapon systems already available for comparison. The ability of M&S to record and analyze fuzzy data sets [14] provides the opportunity to ensure only the most effective systems are purchased and employed. Factors such as munition production rates and cost should also be considered as a high cost munition may suggest one way drones are more effective in a given application.

4.6 Standardized Interface to Hardware

The hardware interface is another item that can be concurrently developed. The standardized hardware includes Motor, Wheel, Rotor (MWR), communications, control, sensor, and military specific interfaces such as weapons connections. These are complementary development efforts and must consider both physical aspects like connectors and standardized software interfaces to limit proprietary effects on persistent federation.

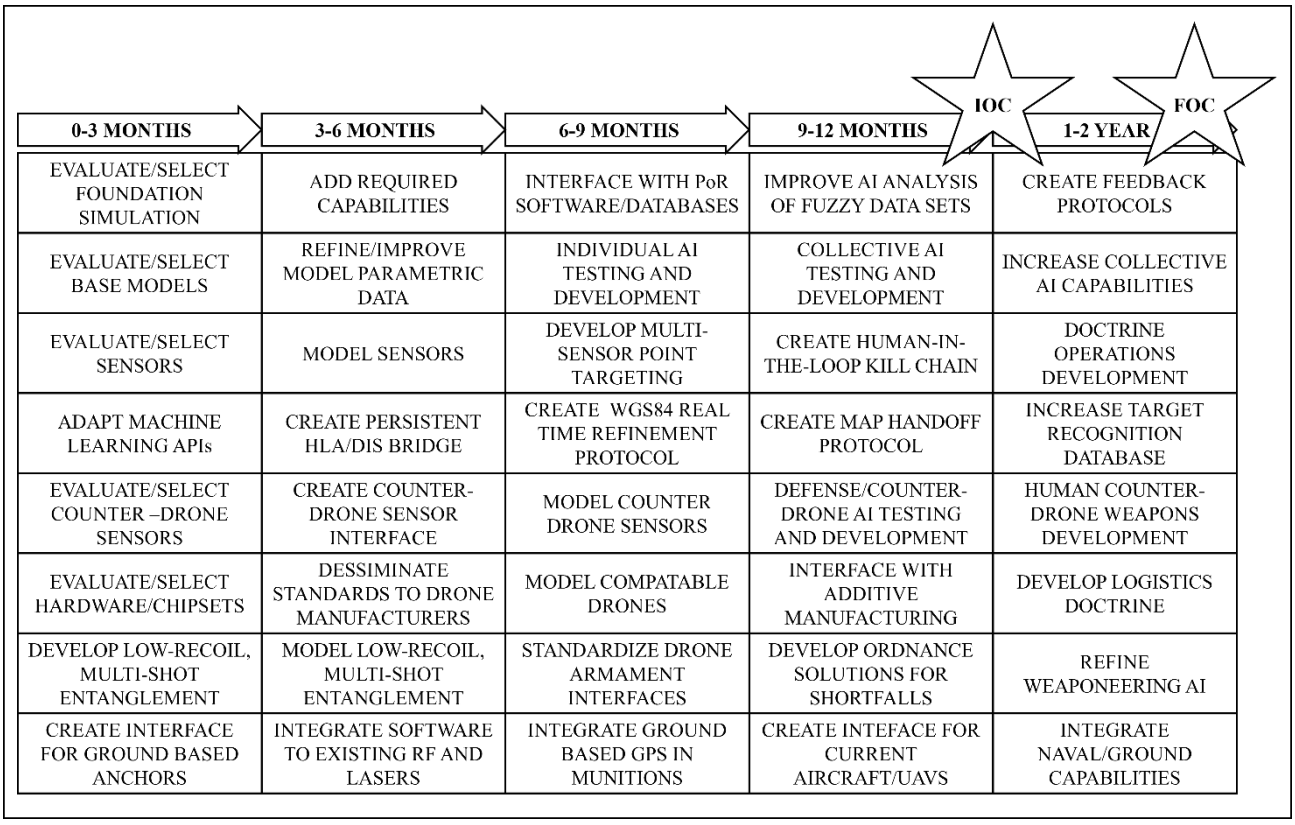
4.7 Considerations for Acquisition

The current funding cycle delays and purchase of completed technologies is counter to rapid advancement of drone technologies. The first step in this process is to identify the models and simulations with the most capabilities in each realm and the highest degree of accuracy. These must be standard foundations to ensure coherency through the process [6], [7] and all sensors, drones, and M&S plug-ins will be specific to the base simulation.

Current systems should be evaluated for their ability to act as the standard with consideration to weapons, sensors, and drones to limit cost and time associated with modification. While hardware and software interfaces can be used, they increase logistical demands and are counter to the efficiencies of supply chain management in this concept. All future combat systems should also be required to have a provision for accurate modelling and communications interface to provide IFF.

Figure 4-1 shows the development and acquisitions priorities, sequencing, and timelines to Initial Operating Capability (IOC) and Full Operating Capability (FOC).

Figure 4-1: Combined Development Schedule



0-3 MONTHS	3-6 MONTHS	6-9 MONTHS	9-12 MONTHS	1-2 YEAR
EVALUATE/SELECT FOUNDATION SIMULATION	ADD REQUIRED CAPABILITIES	INTERFACE WITH PoR SOFTWARE/DATABASES	IMPROVE AI ANALYSIS OF FUZZY DATA SETS	CREATE FEEDBACK PROTOCOLS
EVALUATE/SELECT BASE MODELS	REFINE/IMPROVE MODEL PARAMETRIC DATA	INDIVIDUAL AI TESTING AND DEVELOPMENT	COLLECTIVE AI TESTING AND DEVELOPMENT	INCREASE COLLECTIVE AI CAPABILITIES
EVALUATE/SELECT SENSORS	MODEL SENSORS	DEVELOP MULTI-SENSOR POINT TARGETING	CREATE HUMAN-IN-THE-LOOP KILL CHAIN	DOCTRINE OPERATIONS DEVELOPMENT
ADAPT MACHINE LEARNING APIs	CREATE PERSISTENT HLA/DIS BRIDGE	CREATE WGS84 REAL TIME REFINEMENT PROTOCOL	CREATE MAP HANDOFF PROTOCOL	INCREASE TARGET RECOGNITION DATABASE
EVALUATE/SELECT COUNTER –DRONE SENSORS	CREATE COUNTER-DRONE SENSOR INTERFACE	MODEL COUNTER DRONE SENSORS	DEFENSE/COUNTER-DRONE AI TESTING AND DEVELOPMENT	HUMAN COUNTER-DRONE WEAPONS DEVELOPMENT
EVALUATE/SELECT HARDWARE/CHIPSETS	DESSIMINATE STANDARDS TO DRONE MANUFACTURERS	MODEL COMPATABLE DRONES	INTERFACE WITH ADDITIVE MANUFACTURING	DEVELOP LOGISTICS DOCTRINE
DEVELOP LOW-RECOIL, MULTI-SHOT ENTANGLEMENT	MODEL LOW-RECOIL, MULTI-SHOT ENTANGLEMENT	STANDARDIZE DRONE ARMAMENT INTERFACES	DEVELOP ORDNANCE SOLUTIONS FOR SHORTFALLS	REFINE WEAPONEERING AI
CREATE INTERFACE FOR GROUND BASED ANCHORS	INTEGRATE SOFTWARE TO EXISTING RF AND LASERS	INTEGRATE GROUND BASED GPS IN MUNITIONS	CREATE INTEFACE FOR CURRENT AIRCRAFT/UAVS	INTEGRATE NAVAL/GROUND CAPABILITIES

5.0 LIMITATIONS AND LONG-TERM ADVANCEMENT

This development timeline reflects a short-term estimate of capabilities that can be adapted or developed in one year from funding and staffing based on capabilities previously adapted from M&S. Mid-term provisions would include capabilities to integrate humans and drones in the same operational space and urban capabilities development. Long-term efforts would most likely focus on advancing capabilities to commercial technology and countering adversary advancements. To the most extent, technology development should be government led and owned supplemented by purchase of patents from industry because this concept relies on producing the maximum number of drones within the battlespace and not purchasing them from defense contractors.

Consideration should also be given to the strategic value to M&S beyond drone swarms in a contest with a pace-threat. A contested space domain will likely have a detrimental effect on satellite-based GPS. Local anchoring within the battlespace also presents a resiliency to civilian needs when applied to sustaining industrial, economic, and emergency operations. These civilian applications may benefit from partnership with academia and industry to better geo-rectify RF emitting ground anchors to create a robust network that does not singularly rely upon satellites for all uses of GPS.

6.0 CONCLUSIONS

The commonalities between M&S and PoR systems provides the opportunity to view the physical world as a

M&S battlespace. By doing this, accurate models and parametric data can be used beyond training and education. The advanced AI coupled with SQL database management provide opportunities to understand the environment to integrate drones. The challenges of persistent HLA/DIS federation are remedied with the ability to aggregate and disaggregate individual and collective drones. Layered AI remedies inconsistencies of action that increase susceptibility to adversary action.

The incorporation of machine learning provides for rapid TTP development, conceptual testing, and rapid adaptation to battlefield conditions or adversary actions. Shortened and standardized supply lines protect a critical vulnerability of warfare. Blockchain technology provides for better database management, encryption, and laser target designation. A temporary local GPS increases the accuracy of conventional guided weapons.

Internal kill chain execution and terminal guidance creates drones that can penetrate and operate within a contested EMR, GPS denied, and ECM rich environment. Weapons considerations and developmental testing are aided using M&S leading to potential defensive and counter-drone advantages. While this has focused on the value of M&S as an operational capability, it has also identified supporting disciplines and complementary efforts. Most importantly, this concept places primacy on available technologies for the most expeditious deployment in active combat zones or for adversary deterrence.

7.0 REFERENCES

[1] Bera, B., Saha, S., Das, A. K., Kumar, N., Lorenz, P., & Alazab, M. (2020). Blockchain-envisioned secure data delivery and collection scheme for 5G-based IoT-enabled internet of drones environment. IEEE Transactions on Vehicular Technology, 69(8), 9097-9111. https://doi.org/10.1109/TVT.2020.3000576

[2] Cao, X., Liu, Z., Hu, C., Song, X., Quaye, J. A., & Lu, N. (2024). Three-dimensional geological modelling in earth science research: An in-depth review and perspective analysis. Minerals (Basel), 14(7), 686. https://doi.org/10.3390/min14070686

[3] Davidson, J. B., Graham, R. B., Beck, S., Marler, R. T., & Fischer, S. L. (2021). Improving human-in-the-loop simulation to optimize soldier-systems integration. Applied Ergonomics, 90, 103267-103267. https://doi.org/10.1016/j.apergo.2020.103267

[4] Källström, J., Granlund, R., & Heintz, F. (2022). Design of simulation-based pilot training systems using machine learning agents. Aeronautical Journal, 126(1300), 907-931. https://doi.org/10.1017/aer.2022.8

[5] Kasım, B., Çavdar, A. B., Nacar, M. A., & Çayırcı, E. (2021). Modeling and simulation as a service for joint military space operations simulation. Journal of Defense Modeling and Simulation, 18(1), 29-38. https://doi.org/10.1177/1548512919882499

[6] Lu, F., Hu, X., Zhao, B., Jiang, X., Liu, D., Lai, J., & Wang, Z. (2023). Review of the research progress in combat simulation software. Applied Sciences, 13(9), 5571. https://doi.org/10.3390/app13095571

[7] Nohel, J., Stodola, P., Flasar, Z., & Rybanský, M. (2023). Multiple maneuver model of cooperating ground combat troops. Journal of Defense Modeling and Simulation, 20(4), 481-493. https://doi.org/10.1177/15485129221078939

[8] Shaoqin, W., Bingli, X., Shulai, N., Xiaoyao, S., Congjie, G., & Lin, L. (2020). Behavior modeling method and its application in combat simulation. IOP Conference Series. Earth and Environmental

Science, 502(1), 12018. https://doi.org/10.1088/1755-1315/502/1/012018

[9] Trias, C. E. D. (2023). Modeling and simulation in mission assurance. Journal of Defense Modeling and Simulation, 20(2), 109-110. https://doi.org/10.1177/15485129221105084

[10] Virca, I., Bârsan, G., Oancea, R., & Vesa, C. (2021). Applications of augmented reality technology in the military educational field. Land Forces Academy Review, 26(4), 337-347. https://doi.org/10.2478/raft-2021-0044

[11] Wu, T., Zou, Q., Wu, J., Wang, H., & Zang, M. (2021). Hardware in the loop simulation training system based on HLA architecture. Journal of Physics. Conference Series, 1976(1), 12045. https://doi.org/10.1088/1742-6596/1976/1/012045

[12] Wu, Y., Dai, H., Wang, H., & Choo, K. R. (2021). Blockchain-based privacy preservation for 5G-enabled drone communications. IEEE Network, 35(1), 50-56. https://doi.org/10.1109/MNET.011.2000166

[13] Zhang, H., & Hanzo, L. (2020). Federated learning assisted multi-UAV networks. IEEE Transactions on Vehicular Technology, 69(11), 14104-14109. https://doi.org/10.1109/TVT.2020.3028011

[14] Zhang, S., & Shi, X. (2020). Simulation training effectiveness evaluation based on fuzzy comprehensive evaluation. Journal of Physics. Conference Series, 1624(2), 22064. https://doi.org/10.1088/1742-6596/1624/2/022064

