Temasek Defence Systems Institute

ANALYSIS OF LAND-BASED C-UAS PLATFORM: AN INVESTIGATION INTO KINETIC VERSUS DIRECTED ENERGY WEAPONS

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Introduction and Background

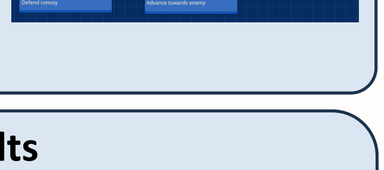
Warfare historically favoured larger fighting forces with superior technology in battles of attrition, often in direct engagements with adversaries. Modern technological advancements enabled a paradigm shift in operations, where small and low-cost unmanned aerial systems (UAS) have proliferated across various regions, posing problems for forces wanting to defend against UAS attacks. The development of directed energy weapons (DEW), such as high energy lasers (HEL), have increased the variety of counter-UAS (C-UAS) options for defenders to employ. However, there exists a gap in studies related to the protection effectiveness afforded by mobile C-UAS platforms. In this work, a representative DEW system was modelled and compared against traditional kinetic energy (KE) weapon.

Methodology and Tools Used

UAS threats in this study were selected to represent Group I UAS, based on DoD UAS classification [1].

The virtual environment and entities were generated using Swarm Commander Tactics (SCT), an in-house application developed by NPS MOVES Institute to study swarm tactics using simplified platforms and realistic directed energy propagation and damage, effectively modelling interactions between UAS and C-UAS elements [2].

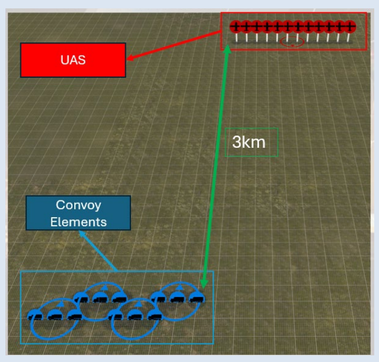
The parameters for each weapon system were established, while the behaviour of each entity was also defined within SCT, using conditional “if-else” logic flow.



Simulation Model

The analysis involved the protection of 12 convoy trucks using two C-UAS platforms against an incoming UAS attack.

Four variables were identified, with UAS Location, UAS Quantity, C-UAS Location and C-UAS Weapon selected. 16 scenarios were generated using Design of Experiments (DoE) feature in Minitab.



Simulations Results

Five metrics were identified to analyse the results: 1) Number of Survived Convoy, 2) Number of UAS Killed, 3) Shortest Distance between UAS & Convoy, 4) Difference between Shortest and Furthest Distance between UAS and Convoy (Hi-Lo), and 5) Time to Complete UAS Engagement.

For all simulations, the addition of C-UAS platforms resulted in zero convoys lost and all UAS killed, thus only the latter three metrics would be analysed. The quantitative results were extracted and compiled.

	Scenario	Baseline		Swarm		Ambush		Combined	
Shortest Distance to Convoy	C-UAS Location	Front	Side	Front	Side	Front	Side	Front	Side
	DE	675.67	487.44	654.67	493.94	546.06	492.03	612.89	582.60
	KE	639.36	490.36	458.36	320.42	632.92	572.28	572.15	522.67
	Difference	**0.95**	**1.01**	**0.70**	**0.65**	**1.16**	**1.16**	**0.93**	**0.90**

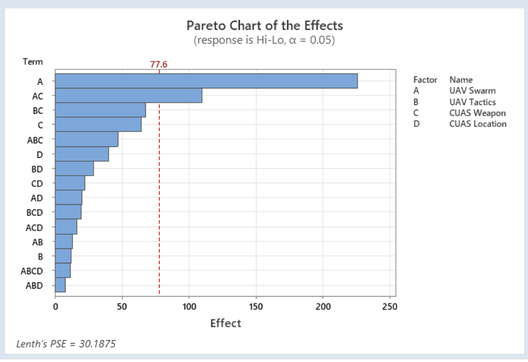
	Scenario	Baseline		Swarm		Ambush		Combined	
Hi-Lo	C-UAS Location	Front	Side	Front	Side	Front	Side	Front	Side
	DE	153.00	160.67	235.00	243.33	192.33	212.33	335.33	369.67
	KE	144.00	111.33	492.67	562.67	89.67	183.67	348.00	476.33
	Difference	**0.94**	**0.69**	**2.10**	**2.31**	**0.47**	**0.87**	**1.04**	**1.29**

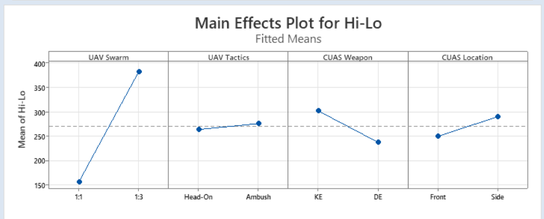
	Scenario	Baseline		Swarm		Ambush		Combined	
Time of Engagement	C-UAS Location	Front	Side	Front	Side	Front	Side	Front	Side
	DE	1.65	3.43	8.67	7.95	4.96	6.96	7.87	17.68
	KE	5.44	6.49	21.19	19.87	5.17	10.55	17.64	20.16
	Difference	**3.30**	**1.89**	**2.44**	**2.50**	**1.04**	**1.52**	**2.24**	**1.14**

Analysis of Results

The results were further analysed to identify variables with statistical significance using Minitab. Both “UAS Quantity” and “C-UAS Weapon” showed significant impact on the outcome of the UAS engagement.

It was observed that a larger UAS swarm would easily overwhelm defences, while DEW systems performed better than KE weapons.

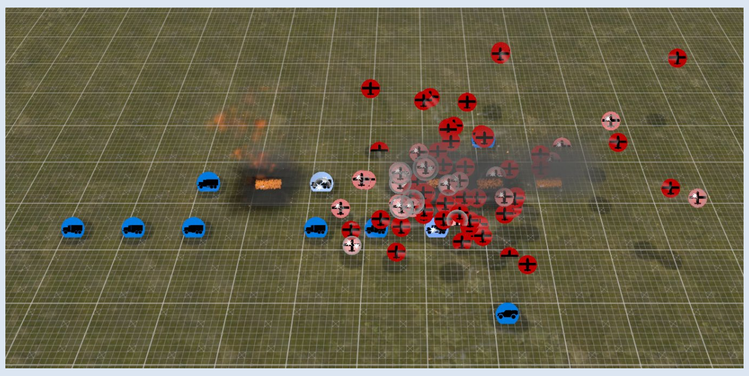




“Breaking the System” Scenario

Using the identified variables, additional models were generated to identify the breaking point of the system. It was determined that a UAS quantity multiplier of **15** was needed for DE weapon, while a value of **12** for KE weapon was required per convoy truck to defeat the C-UAS system.

The increased effectiveness of the HEL system meant a larger number of UAS was required to defeat the protection bubble provided by the C-UAS platforms.



Conclusion and Future Work

In this work, a virtual convoy was assaulted by a UAS swarm in SCT. The protection by mobile C-UAS platforms was analysed, and determined to be influenced by the **quantity of UAS** and the **C-UAS weapon system**. The two C-UAS protection tactic was then “broken” by swarming the convoy with a multiplier of **12-15** UAS per convoy. It is recommended for DE weapons to be used for long range engagements, giving them sufficient dwell time to destroy the UAS, before transitioning to KE weapons for engagements at shorter ranges where speed is crucial.

Work was limited by the functionality within the existing software, and future work involving terrain or atmospheric effects as well as parametric studies of weapon effects is recommended once the capability is implemented, resulting in more robust CONOPS analysis for C-UAS protection.

[1] D. Gettinger, “Defense Primer: Categories of Uncrewed Aircraft Systems,” 25 Oct 2024. [Online]. Available: https://www.congress.gov/crs-product/IF12797. [Accessed 16 Aug 2025].
[2] R. (. Johnson, “Swarm Commander Tactics,” 02 Aug 2021. [Online]. Available: https://gitlab.nps.edu/moves/swarm-commander-tactics/-/wikis/Public-Relations/Description. [Accessed 23 July 2025].

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