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Military Potential of Swarm Intelligence



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Instead of Marines being the first wave in, it'll be unmanned robotics ... sensing, locating and maybe killing out front of those Marines. We see that 'swarm-type' technology as exactly the type of thing – it will lower cost, dominate the battle space, leverage capabilities...and be able to complicate the problems for the enemy.¹

– Lt. Gen. Robert Walsh, the Service's Commanding General for Combat Development, US Army

Swarming is currently considered to be one of the most promising areas of defence technology development in the world. The Chinese are prioritising it.²

– Vasily Kashin, an expert on China's military at the Higher School of Economics, Moscow.

Introduction

Swarm intelligence (SI) is the collective behaviour of decentralised, self-organised systems, which can be natural or artificial. SI systems typically consist of a population of simple agents interacting locally with one another and with their environment. The inspiration often comes from nature, especially biological systems.

The agents follow very simple rules and although there is no centralised control structure dictating how individual agents

Key Points

1. Swarm Intelligence (SI) is the collective behavior of decentralized, self-organized systems, which can be natural or artificial.
2. The characterizing property of a swarm intelligence system is its ability to act in a coordinated way without the presence of a coordinator or of an external controller.
3. Swarming occurs when several units conduct a convergent attack on a target from multiple axes.
4. Drones swarming the battlefield or an airfield in the thousands would be very difficult to counter.
5. Policy makers need to undertake holistic appreciation of the drone swarm threat through terrorists that are state-sponsored anyway, as well as contemporary conflict situations, putting countermeasures in place.

The Centre for Land Warfare Studies (CLAWS), New Delhi, is an autonomous think-tank dealing with national security and conceptual aspects of land warfare, including conventional and sub-conventional conflict and terrorism. CLAWS conducts research that is futuristic in outlook and policy-oriented in approach.

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should behave, interactions between such agents lead to the emergence of 'intelligent' global behaviour, unknown to the individual agents.³

The characterising property of an SI system is its ability to act in a coordinated way without the presence of a coordinator or an external controller. Many examples can be observed in nature of swarms that perform some collective behaviour without any individual controlling the group or being aware of the overall group behaviour. The typical SI system has the following properties:⁴

- It is composed of many individuals.
- The individuals are relatively homogeneous (i.e. they are either all identical or they belong to a few typologies).
- The interactions among the individuals are based on simple behavioural rules that exploit only local information that the individuals exchange directly or through the environment.
- The overall behaviour of the system results from the interactions of individuals with each other and with their environment, that is, the group behaviour self-organises.

Military Potential of SI

Swarming occurs when several units conduct a convergent attack on a target from multiple axes. It involves pulsing, where units rapidly converge on a target, attack it and then disappear. Swarming is of two types, one where units arrive on a battlefield as a single mass, disassemble and attack the enemy from many directions, and the second, where the dispersed units converge and attack without forming a single mass. Five variables are essential for a swarm attack to be successful. These are superior situational awareness, elusiveness, standoff capability, encirclement and simultaneity.⁵

Future warfare will be unmanned, invisible, and silent with ever-higher degrees of 'intelligentisation'. Military strategists expect that future autonomous combat involving unmanned systems as well as the joint operations of unmanned and manned systems will have a dramatic impact on traditional operational models. Future unmanned systems swarming will

involve 'intelligentised' and semi- or fully autonomous systems.

The disruptive potential of SI techniques could be used for saturation assaults to overwhelm the defenses of high-value targets, including fighter jets or aircraft carriers. In particular, the anticipated advantages of intelligent swarming drones include their functional distribution, high system survivability and low operational cost. These systems could engage in intelligence, surveillance and reconnaissance, offensive operations, whether independently or in coordination with other weapon systems as well as electronic warfare, thus supporting critical areas of strategic deterrence, operational confrontation and tactical operations and will cause a paradigm shift in warfare.

Swarm Weapons Leading to Paradigm Shift in Warfare

The experts are calling the use of artificial intelligence (AI) as the fourth revolution in warfare after the invention of gunpowder, mechanisation and nuclear weapons. Drone swarms are fast becoming potent weapons and with advancement in technology, introduction of SI-based weapons in a regimented way is not distant future. They could become cheap and expendable weapon systems to execute many types of military operations such as attacks on ammunition dumps, communication centres, formation headquarters, airfields, helipads, naval ships, urban warfare and sub-conventional operations.

Drone swarms are now being conceptualised as canister-launched weapons, especially the quadcopter ones, which would make them easy to pack and carry. Tens of drones could be launched from a single vehicle-mounted canister, even while on the move. Launching a swarm of hundreds of drones would probably require only a few vehicles. These could be airdropped through fighter or transport aircrafts or through bigger drones, over or close to target, depending on the danger level in the airspace in the target zone. Once released, the drones would swarm up, proceed to the target area, attempt target recognition based on algorithmic logic and then attack the identified targets. Modern-day battery-powered drones could penetrate the battlefield in depth.

Drones swarming the battlefield or an airfield in thousands would be very difficult to counter. Hundreds of drones over a battlefield or an airfield would saturate the airspace and counter-swarm resources invariably would run short. Indiscriminate firing with small arms to shoot down low-flying swarms may prove counterproductive. EW resources would be able to counter a few but only in a large swarm. Since these are small and move fast, only a few may be shot down and many others would be able to get to their targets. Swarms could also be integrated with fighter aircrafts or attack helicopter missions to increase their safety during missions. Drone swarms could readily take on tasks in contaminated environments having radiation, chemical or biological hazards or in dangerous situations where the odds are heavily against their own forces and the likely casualties to their own forces could be high.⁶ Many countries have taken note of this emerging weapon technology and demonstrated their capabilities in this field.

Capabilities of Leading Nations and Indian Context in SI

China

Chinese advances in AI, including deep learning techniques, have enabled considerable progress in SI. There is ongoing technical and conceptual research, development and testing across Chinese academic institutions, the private sector, defence industry and military research institutes to support such capabilities. The People's Liberation Army (PLA) is clearly seeking the capability to leverage adaptive, intelligent unmanned systems across multiple domains of warfare, including swarming tactics and manned-unmanned weapon system teaming. The PLA's advances in intelligent unmanned systems and swarm tactics could serve as a force multiplier for its future military capabilities.

In November 2016, China revealed its progress in SI with a formation of 67 small fixed-wing unmanned aerial vehicles (UAVs) utilising autonomous swarm control and dynamic centreless networks for communication and coordination among UAVs. Such swarms could be used for reconnaissance, strike, jamming and other missions. In the spring of 2017, a formation of 1000 UAVs at the Guangzhou Air Show by a private company reportedly broke records again. At that time,

AI and autonomous robotic systems, military experts quoted in Chinese media, similarly highlighted that this technique could be used to create a distributed system with payload modules mounted on small drones.⁷

China's future capabilities in SI, military-use AI, will be enabled by high-level plans and extensive funding. China's new national roadmap for AI advances an ambitious agenda for the development of this critical emerging technology through 2030. The Central Military Commission's Equipment Development Department's Scientific Research and Procurements Bureau issued guidelines for pre-research funding under the 13th Five-Year Plan through which funding will be directed to a number of topics that relate to enabling drone swarming, including:

- Research on 'bee swarm' drones on self-organising network architectures, associated monitoring and control technologies, swarm networking and positioning technology, and network antijamming technologies.
- Highly reliable autonomous flight control technology for new energy ultralong endurance drones.
- Technologies for intelligent identification of targets and adaptive patterns for analysis based on deep reinforcement learning with large-scale remote sensing data.
- Methods for brain-like learning algorithms able to engage in sensing in an unstructured environment.

As of 2017, under the National Defense Science and Technology Key Laboratory Fund expenditure head, China has also committed to funding multiple projects related to AI and drone swarming, including the following:

- Intelligent task planning technology to improve the management of unmanned swarms based on deep learning by China Aerospace Radio and Electronics Research Institute.
- AI methods for unmanned vehicles to adapt in complex maritime environments by Harbin Engineering University.
- Comprehensive decision-making, management and control technology for advanced drones, including

control and management technology for manned-unmanned cooperation, in order to achieve the integration, intelligentisation and networking by Beihang University.

At present, multiple military and civilian research institutes appear to be working on swarming drones. Based on their published research and patents on the topic, following institutes are pioneering in this technology:

- China Electronics Technology Group Corporation,
- UAV Technology Research Institute which is part of China Aerospace Science and Industry Corporation,
- National Key Laboratory of Robotic Systems and Engineering which is a part of Harbin Institute of Technology,
- Tsinghua University,
- Beihang University,
- Harbin Engineering University,
- Northwestern Polytechnical University.

China is heavily investing in next-generation defence technologies which are more and more indistinguishable from the civilian technologies and same can be easily mass produced by the Chinese industry. While recent breakthroughs in stealth and precision guidance were purely military applications, the next round might be in areas such as facial recognition or autonomous driving, which are likely to come from the private sector. China has become the market leader in commercial drones, as well as a robust exporter of military drones based on US models like the Reaper and the Predator, to countries like Iraq and Saudi Arabia. The importance of civil-military fusion has been recognised by President Xi Jinping, who created a Military-Civil Integration Development Commission this year with himself as the head.⁸

The United States of America

The Science Research Division of Department of Defense (DoD) concluded in a report that in order to destroy adversaries and protect American assets in equal portions, AI will be a crucial part of the nation's ongoing defence strategy. The US Military already uses a host of robotic systems in the battlefield, from

reconnaissance and attack drones to bomb disposal robots. However, these are all remotely piloted systems, meaning a human has a high level of control over the machine's actions at all times. The new DoD report sees tactical advantages from humans and purely self-driven machines working together in the field. In one scenario, a swarm of autonomous drones would flock above a combat zone to jam enemy communications, provide real-time surveillance of the area and autonomously fire against the enemy.⁹

The United States' Low-Cost Unmanned Aerial Vehicle Swarming Technology (LOCUST) Program, for instance, exhibits a system that rapidly discharges drones into the air from a single tube, as an anti-aircraft gun spewing hundreds of rounds in seconds. Under this program a large quantity of small drones are folded up into tubes, and then put into the sky to cover and scout an area together. The LOCUST system is being developed and tested by the Office of Naval Research. For decades, the United States has fielded aircraft more expensive than the weapons used to knock them out of the sky. One solution to this is stealth planes, which are much harder for anti-aircraft missiles to hit. Another option, which is provided by SI, is instead to throw lots of smaller, cheaper robots into the sky and let the enemy waste expensive anti-aircraft missiles on drones, while redundant swarm members complete the mission.¹⁰

In October 2016, the Strategic Capabilities Office of the DoD in partnership with Naval Air Systems Command, successfully demonstrated one of the world's largest microdrone swarms at China Lake, California. The test consisted of 103 Perdix drones launched from three F/A-18 Super Hornets. The microdrones demonstrated advanced swarm behaviours such as collective decision-making, adaptive formation flying and self-healing.¹¹

Indian Context

In the field of SI, research and development activities are in very nascent stages and restricted to institutions such as Indian Institutes of technology and Indian Institute of Science. India has not demonstrated any capability in commercial and military applications of SI till date. India needs to focus on the development of swarm weapons and recommendations in this regard are given in succeeding paragraphs.

Recommendations

Armoured warfare began during the First World War with the need to break the effectiveness of entrenched defensive infantry and return to manoeuvre warfare to offer armour protection to troops against small arms fire as they were manoeuvring. This led to a rise in armoured units and formations to have a decisive advantage over entrenched enemy. Apropos, in order to gain and maintain combat superiority in this era of rapidly changing technology and to have strategic deterrence, it is imperative to raise units and subunits equipped with SI-based weapon systems and appropriate training to the users be imparted under realistic conditions. To achieve the offered objective, following is recommended:

- **Operational Needs:** Operational needs are required to be identified based on varied terrain, various operations of war and sub-conventional operations. Also, capabilities of adversaries need to be focused upon while determining the said needs.
- **Identification of Platforms and Solutions:** Identifying appropriate technology and time-bound deployment of the same is the need of the hour. For speedy procurement, already developed and available technology may be utilised and innovative procurement policy be formulated.
- **Profiling and Equipping of Mission-oriented Combat Teams:** Equipment profile, manpower (skilled and unskilled) and other administrative requirements required to be worked out and the process of raising of mission-oriented combat teams equipped with weaponised SI-based systems to be undertaken immediately.

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- **Training:** All ranks to be trained by physically using these types of weapon systems and to be exercised adequately to hone their skill across varied terrain and all operations of war.
- **Innovative Human Resource (HR) Policy:** Talent pool is required to be created for the development, maintenance and imparting training on these types of weapon systems through innovative HR policy and remunerations to be offered at par with the industry to attract the right talent.
- **Indigenous Development of SI and Counter-SI Technology:** There is a need to encourage the indigenous development of SI and Counter-SI technology through progressive research and development and a suitable funding model.

Conclusion

It is obligatory that armed forces take note of the fast trajectory of development of these types of weapon systems which are transforming the nature of war. The military needs to understand the impact of swarm weapons on the nation's offensive and defensive capabilities and start working on the indigenous development of these technologies. Unless this happens quickly, the nation risks preparing for a 20th-century war against 21st-century armies.

Policymakers need to undertake holistic appreciation of the drone swarm threat through terrorists that are state-sponsored anyway, as well as contemporary conflict situations, putting countermeasures in place. Introspection is also required as our adversary is not only manufacturing these types of weapon systems but also exporting them and India is not even producing prototypes of the same. Needless to say, a quid pro quo capability is the need of the hour.

of Swarm Intelligences ...

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