Unmanned Battlefield Systems
Future Unknowns

S. Guruprasad*

The Unmanned Systems, either remotely operated or autonomous to different degrees, have already become a part of defence inventory and are fast becoming a significant part of the combat forces apart from being used for Intelligence, Surveillance and Reconnaissance (ISR). The Unmanned Aerial Vehicles (UAVs) with days of endurance and inter-continental ranges with strike capability are redefining war doctrines and operational tactics. The Naval and Ground Forces are going to be new dominions of Unmanned Systems which was till now dominated by UAVs. The real turning point would be teaming up human and Autonomous Unmanned Systems, be it any battlespace. Another area would be collaboration of Air, Ground and Naval Heterogeneous Unmanned Systems with quick formation of operational autonomous teams. It is important to acknowledge that the human tactical judgement with critical information at hand cannot be replaced by algorithmic computations whether based on deterministic models or Artificial Intelligence. The so-called situational awareness can be comprehended better by a well-experienced battlefield commander rather than a laboratory-trained autonomous system. The teaming up would be challenging in complex situations, especially in identification of friend and foe, decoys, and in prioritising targets. The Autonomous Systems will need to learn to conserve energy and ammunition and have survival skills to tackle adverse situations. Another important domain would be the development of 'autonomous by birth' platforms that would outperform all manned platforms, especially large platforms. Inherently, the limitations of human attention duration and the biological necessities

* Dr S. Guruprasad is former Director General (Production Coordination & Services Interaction) and a Distinguished Scientist retired from Defence Research Development Organisation, India.

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were major challenges for defence system designers. The Unmanned Autonomous Systems (UAS) overcome these limitations at the same time foregoing the unique human acumen and heuristic knowledge. The possibility of compactness, the risk-taking ability and immense endurance and range, and above all, the numbers that can be deployed outweigh every aspect. The domain of Unmanned Battlefield Systems is still in infancy and has pioneer advantage and hence will always define the leaders. The domain belongs to those who dare and don't dither the unknowns and uncertainties. The simple rule for innovations in this domain would be to fail fast and develop faster.

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Introduction

The first application of robots was at nuclear reactors to load and retract fuel rods, a hazardous task that was absolutely necessary to be done remotely using manipulators and grippers. The industrial robots made a big entry into production lines because of the need for flexible manufacturing plants. The application of robots for repeated as well as hazardous tasks has become a norm of the industry because of their flexibility to adapt to new tasks. The remote operations of these systems with or without wire have already been mastered by the industry. During the World War II, the Goliath tracked Mine was used by Germans. Everett[1] has well documented this Remotely Operated System and other development of Unmanned Systems. The basic idea of the Goliath was to kill something big with something small and inexpensive; this is the primary idea behind all Unmanned Systems even today, broadly it is to achieve more with less. It is unthinkable that any defence planning for the future would leave out Unmanned Systems. The conventional defence technologies have always relied and thrived on technological advances in core technologies of sensors, propulsion, guidance, armaments, etc. There is no doubt that research in these core technologies will continue with the same intensity, however, innovations using the unmanned platforms are going to provide unprecedented power to the forces. In fact, the technologies used in today's unmanned systems were available since long, it is the drive of innovation and new confidence level that is fuelling the new growth.

The Kamikaze pilots of Japan's special forces demonstrated the lethality of a flying machine on a suicide mission highlighting the fact that if the pilot is operating the aircraft remotely, the risk-taking ability multiplies manifold. However, the first higher technology applications of the Unmanned Aerial Vehicles (UAVs) were for Intelligence, Surveillance and Reconnaissance (ISR) roles with higher endurance and range and with higher acceptability of being shot down compared to a manned aircraft. Especially in an aerial platform, removing the man on board provides huge advantages; firstly, removing the risk of precious life of the pilot, and secondly, the availability of extra space and weight. The manned aircraft would only engage in very special situations, leaving most of the tasks to Remotely Piloted Platforms including combat duties.

It is pertinent to recall the U2 spy planes[2] of US flying at very high altitudes that were carrying out reconnaissance mission on Soviet Union. There were no weapons to shoot down these planes initially. Such missiles were developed eventually. The US developed SR-71 aircraft that could fly at 3.4 Mach but was soon retired in favour of spy satellites. Now it is the time for UAVs to fill this space, if not entirely. A swarm of UAVs networking and covering a huge area can provide good amount of intelligence and communication coverage.

The emergence of Artificial Intelligence (AI) as a major enabler with the maturity of learning algorithms is going to be the main workhorse for unmanned systems. To be specific, the image processing and inference engines based on AI have been major developments in recent times. These include face recognition, identification and classification of targets—whether a man is carrying a gun or a staff, whether a vehicle is a worthy military target or not. The important aspect is how well the AI systems can be trained and how robust will be their inferencing and what will happen when there are counterintuitive situations. It must be accepted that a human experienced in the domain may be slow and can make mistakes but when it comes to unknowns, his heuristics and intuition may be a better bet.

The entire modern warfare hinges on communication domain and whoever dominates this domain in the battlefield will have a huge advantage. Entire Unmanned Systems without a robust communication system would render itself useless. Space assets that enable effective communication with the command centres are even more important.

It is the concept of 'swarms' that is most exciting wherein the individual entities of the swarm may have very simple sensors and controllers but in a formation with simple swarm algorithms they can be a significant force and there is no counter for them when they attack a conventional platform. Imagine a scenario when an antiship missile delivers a swarm near its target; these swarm entities carrying small explosive charges can hit the vital systems of the battleship or can do anything including holding the ship under siege. Presently, only imaginable credible countermeasure for a swarm is an anti-swarm.

The scientific and technological research will continue with the same vigour in core technologies and material sciences especially in non-metallic materials. The future research in Unmanned Systems would be more application-oriented with academicians and defence scientists working together in adapting and configuring technologies involving very serious laboratory simulations and emulations of practical scenarios and training of AI engines that will have to handle these situations.

Future Research Directions

It is prudent to look at some of the possible future thrust areas where significant growth could be anticipated. The technologies that go into building the future Unmanned Systems would be same as what goes into conventional war machines, however, there would be a few important applied research areas that would need immediate focus and efforts.

Communication Systems

The first and foremost is to have the capability to seamlessly communicate with heterogeneous systems that will have different origins and build dates. Everything all the time cannot be latest and state-of-the-art. There is a need for establishing a backbone that will deal with all of the most advanced and legacy systems seamlessly so that the human commanders in command centres get quick updates and comprehend the situation and give appropriate directions to these unmanned systems. Distributed communication networks with fault tolerance and with quick reconfiguration capability would be needed. These networks should be capable of using multiple resources, viz., satellites, UAVs, ground-based fibre optic networks, wireless networks of different bands with or without repeaters. These systems would be software-driven with capability of establishing a link from battlefield to command centres with whatever best resources available to them. The communication systems need to deal with physical destruction of landlines, jamming of wireless links, etc. It goes without emphasis that the communication networks should have robust encryption, decryption and authentication systems. It is said that whoever dominates the electromagnetic space will be the winner in any future war. It should be acknowledged that modern systems are heavily shielded and are jam-resistant and they can even withstand high-energy pulses. Energy levels required to blind out the enemy platforms to domination level are huge and impractical, if not impossible. Secondly, using satellites, the UAVs as communication platforms, alternate communication channels can be quickly linked. To summarise, whoever has better and robust communication networks and processes data faster and effectively utilises the data available will have huge advantage in handling Unmanned Systems in the battlefield.

Manned–Unmanned Teaming

The Manned and Unmanned Teaming (MUMT) is one such growth direction expected to happen with the primary objective of effective strike on targets with maximum protection to the manned platforms. This brings in the advantage of a superior situational thinker—the human—so that he can direct the unmanned platforms to the best effect. The manned–unmanned teaming may have many technological challenges but it appears to be a research area worth pursuing. A typical scenario could be a conventional fighter jet flying with unmanned platforms. The BAE Systems, Inc., an international defence, aerospace and security company in the US,[3] has already announced the unmanned wingman concept and that the fighter jets that can use the unmanned wingman aircraft have much more survival capability and are more lethal. Northrop Grumman too has published a paper[4] bringing out a typical scenario of operation wherein a swarm of UAVs jam the enemy radars and autonomously engage in combat while a rescue operation is being carried out. The kind of cooperation among the manned and unmanned platforms and the tactical scenarios need to be imagined and worked out by respective professionals. The different scenarios in teaming have to be simulated, emulated and training of the AI engines and human operators has to be carried out.

Swarm Systems

The swarms of UAVs, Unmanned Ground Vehicles and Unmanned Surface and Sub-Surface Sea systems can unleash disproportionate destruction to the conventional platforms that do not have any countermeasure against these systems. A battle tank if surrounded by a swarm with explosives has no chance of survival just by numbers. The electronic countermeasures may or may not work depending on how these entities are designed to function in challenged environments. It is hard to imagine the fate of conventional platforms against swarms.

The classical method of using decoys like flares, chaff, high-intensity radiation to blind the seekers, reflectors, emulators of thermal signatures may not be useful against swarms. It is unlike a single warhead heading towards a target where you may even shoot it down with an anti-missile system. Swarm of UAVs are easier to build and deploy in numbers, they can be delivered by a larger UAV to a place close enough to target, yet far enough for its own safety. It is similar to an anti-ship missile fired from a fighter jet from a long range. The aircraft never enters into the range of anti-aircraft missiles of the ship, but the range is enough for the anti-ship missile to reach the target.

Swarms depend on swarm algorithms that would evolve by training them in simulated environments either in computer models or in an experimental set-up in a laboratory. Eric Bonabeau, Marco Dorigo and Guy Theraulaz, in their book[5], provide a good insight into the swarm algorithms. The combinations of Artificial Neural Networks (ANN), Genetic Algorithms (GA), Fuzzy Logic, Graph Theory, etc., became the basic tools of learning and building Artificial Intelligence Systems. These AI-based systems along with some deterministic algorithms will be able to deal with some of the vital aspects of swarm operations, viz., spread of the swarm, identification of targets and assignment of targets to swarm members, prioritisation of targets, swarm leadership and hierarchy, their moods of operation, viz., conserve energy, bulwark, attack with full force or retreat. Just like natural swarms or herds, they need to have some traits of the biological world for better effectiveness and survival. Some of the scenarios may be self-sacrifice in the larger interest of the tribe. One immediate necessity is to address the issue of identifying friend or foe and to act in best possible way when there is a loss of link with its command centre. A swarm of unmanned battle tanks would be one fourth the cost and size and with more armour to defeat conventional anti-tank shots.

Swarm of satellites in space in Very Low Earth Orbit with shorter life spans would give superior advantage to the forces. There will be a sort of 'Internet of Military Things'.[6]

The future battlefield would be unthinkable without swarms of all kinds. The armed forces have no choice but to either induct them as quickly as possible or face them.

Autonomous-by-Birth

It is not difficult to foresee the emergence of Supersonic Unmanned Combat Aircraft and similarly, Unmanned Battle Tanks, Unmanned

Naval Ships and Submarines that would be much more lethal compared to existing conventional platforms. These systems would be designed with a top-down approach as 'Autonomous-by-birth' and would be capable of operating in swarms with human commanders directing such swarms tactically with tasks of obstacle avoidance, engagement of targets assigned, etc., being performed autonomously. The X-47B of Northrop Grumman has already completed flight trials in semi-autonomous and autonomous modes. It is expected to be inducted for operations in semi-autonomous mode.

Intuitively, it can be comprehended that Autonomous Systems cannot be left on their own as they operate on the basis of what they are taught and in unfamiliar and out-of-syllabus questions, the AI probably may have no answers but the comprehension of humans under utter uncertainties may be far better. The larger platforms like unmanned battle tanks may operate in semi-autonomous mode for operation wherein decisions of firing of weapons will be under human control while rest of the operations like obstacle avoidance and mobility would be autonomous. The possibility of a single operator controlling several platforms will need effective algorithmic development and most importantly, training.

The conversion of near end of life conventional platforms into Unmanned Systems is another option to have a sizeable base of Unmanned Systems until the 'Autonomous-by-birth' type of systems could proliferate. Such a conversion needs to be done with lots of care as most of the sub-systems may need tuning and manual adjustments and even modifications. Conversion of fighter aircraft, battle tanks, naval vessels including submarines may need deeper studies and in case of many large platforms, may not be worth the effort. The Unmanned Systems in future with comparable firepower will be smaller in size and weight and will carry more sensors and will invariably have a complete health monitoring system.

Changing Battlespace

One more important aspect that will drive future developments is the vulnerability of large platforms against the ever-evolving missile technologies. The seekers have become more intelligent and precise, propulsion systems are becoming faster, and hypersonic missiles are not very far. The stage has reached wherein it is more difficult for the armour to beat the ammunition. The future of Large Aircraft Carriers is indeed bleak unless the forces using them could completely dominate the enemy. The only way to offset such a situation is to have high numbers of unmanned systems in swarms that are impossible to fight against. It is to be noted that any countermeasure development lags behind any new weapon of warfare. The Unmanned Systems especially the swarms have that advantage presently. Any armed force that has swarm strike capability will have a huge advantage in the battlefield.

The command centres will need a lot of software to assimilate the immense data flow from the Unmanned Systems. It will not be humanly possible to handle and control the multiple swarms with different missions, hence the command centre software tools need to have capability of prioritising and presenting the situation pictorially for human decision-makers to give commands to autonomous unmanned platform swarms to effectively accomplish their mission. Firstly, we should build such command centres that can handle huge communication traffic. Secondly, the software should be capable of assimilating data and inferring broadly the situation and present the important and vital information that human commanders must know and act upon.

The inventory of the military hardware is going to be heterogeneous and of huge varieties that is opposite the will of the maintenance professionals. Using conventional methods of book-keeping and storekeeping would not be possible. Fortunately, systems can be built with health monitoring and their upgrade and upkeep of records can be automated with software integration and most of the traditional storekeeping can be automated. The variety and huge types of inventories would rather be desirable rather than a bane of maintenance. Even from a managerial point of view, automation of these systems would bring down tail to teeth ratio. However, technical support of these systems needs support of industry houses and training of unmanned systems and human commanders need special laboratory infrastructure.

Futuristic Mine Warfare

Presently, the pressure actuated and influence mines are buried, and these mines wait for the enemy battle tank to accidentally step over to actuate. The buried mines would be truly buried into history for two reasons: first, the laying of mines for kilometres would not deter the enemy as mine detection has become faster and breaching by a mine-plough or mine-flail or a trawl that clear a few mines would create vehicle safe lanes. The powerful mine clearing systems can clear a lane in one or two hours and enemy vehicles can breakthrough rendering the painstakingly created minefield completely useless. Secondly, it is possible to design mines that are intelligent and mobile and make the minefield lethal. The future minefields would be surface mines that are intelligent, provide surveillance against any attempt to breach, and these mines may also be mobile that would heal the minefield quickly denying the passage of enemy vehicles and troops while providing safe passage to own vehicles and personnel. Such an intelligent minefield would be formidable and provide more time for punishing the enemy.

The naval sea-bottom mines are lethal as they are undetectable and the only means to defuse them may be to send down an unmanned sub-surface vessel to visually ascertain and neutralise the mine. The below-the-sea surface mines are presently breached by special mine breaching vessels that have limited endurance. The unmanned swarm of mine breaching autonomous vehicles can effectively perform the task of detecting and neutralising these mines.

Another futuristic application of UAVs would be to protect airfields by physically intercepting low-level cruise missiles and other missiles by various means. The concept is similar to a minefield on ground or in sea. The minefield around an airfield with swarm of UAVs completely protect the airfield from any intrusions. One of the methods of the swarm may be several UAVs carrying a physical barrier like a net and positioning the net in the trajectory of the incoming missile. These may operate autonomously while friendly aircraft would operate without any problem with the swarm providing a safe passage.

Stealth Technologies for Unmanned Systems

The fifth-generation aircraft with stealth technologies would have a huge advantage. The UAVs with the same level of stealth technologies and with smaller Radar Cross Section will become a formidable weapon. As mentioned earlier, all the technologies of conventional platforms would flow into Unmanned Systems. It will be a lethal and formidable weapon if a swarm of these systems, initially dispersed from a swarm, converge to take on enemy positions like airfields, etc. Stealth capability will become important when there will be counter-swarms wherein who can surprise who will become a winning point. Internal weapon bays, flying wing with merged body and serpentine intakes will become essential features of UCAVs. The composite materials with radar absorption inclusions and coatings and morphing wings with minimum reflecting edges will be the future.

Radars for Unmanned Battlefield

It is not difficult to guess the shortcomings of the existing radars against smaller UAVs that have very insignificant RCS. These radars were never intended for the role. It is prudent to bring out the fact that most energy-efficient and compact radars that would give longest range depend on the material technologies and manufacturing technologies of the specific semiconductor technologies. This is a closely guarded technology space and the best of these technologies would be in denial list so that the technology-developing country would always maintain a lead. This has been so for a long time, and it will continue to be so for all advanced materials too, apart from advanced semiconductors. The space-based radars that can do surveillance of large areas would also provide a huge advantage. However, another way is to have unmanned early warning surveillance aircraft with airborne radars that operate as a swarm and give a collective situational data on a continuous basis. These may provide not only data of enemy airfield operations but also the ground activities.

Sea surface surveillance either by UAVs or by Unmanned Surface vessels would provide situational awareness of surface vessel activities. However, the most challenging part would be sub-surface domain which has very low range of sensors and the inconsistency of the medium make the detection of submarines extremely difficult. It will be appropriate to have smaller unmanned submarines operating in the areas of interest to detect any enemy submarine.

Indigenous or Imported Systems

Unlike conventional systems, the unmanned systems are highly vulnerable for kill switch the foreign supplier may have implemented in the code. In fact, it is no secret that all high technology systems supplied from a foreign country will have safeguards so that the weapon cannot be used against the country of origin either because it may fall into wrong hands, or the importing country may turn hostile in future. Secondly, it must be recognised that the main strength of Unmanned Systems is their numbers and their ability to be sacrificed if necessary and all the technology aggregates that go into these systems are mature technologies and innovation in design is the major fulcrum of advantage. Hence, it can be concluded that it is possible to build credible Unmanned Systems within the country with already matured technologies. As the numbers, variety and different sizes would be high, it is prudent that indigenous systems should be inducted with a pace faster than development itself. At the same time, the software upgrades, and upgrades of elements such as sensor units, etc., will have to be done frequently at least in a three-year cycle with maximum life of complete upgrade in 10 years for electronics and software.

There are a number of reasons why the number of Unmanned Systems and their gambit will keep on growing in future. Armed forces always look forward to the technologically best products. However, the growth in innovation and application of technologies would be so fast that it would outpace the conventional field trials, procurement, and induction time cycles. Unconventional systems need unconventional ways to induct, and the armed forces need some innovative managerial processes. The platforms and the technology aggregates have different life cycles and with the new pace the pre-planned product upgrade must be thought early on. Some of the futuristic technologies may be still in theoretical or early laboratory stages. The economics of faster induction and upgrades will neither impress the administrators nor the finance controllers.

Conclusions

The Unmanned Battlefield Systems, especially the Kamikaze drones, are already battle-proven. Swarm technologies with very effective AI would be almost invincible in the battlefield with unmatchable advantage as conventional platforms presently have no countermeasures against such swarms. The main driving force will be innovative designs that utilise already-proven technologies and explore and exploit the unique advantages when a human life is not put into hazard. There is an immense potential for applied research in development and implementation of Artificial Intelligent Systems and training of swarms for specific scenarios. The author's first brush with AI was in 1996 when a fellow research scholar at IIT Bombay was working on ANN and he consulted to confirm whether the network was learning.[7] The learning capability of the network was truly surprising. Later, the author wrote an internal paper[8] in the year 2008 after studying a few academic works on swarms. However, the studies carried out did not fructify into a deliverable product.

All the advanced technologies that are now used in advanced conventional platforms will be deployed in unmanned systems which will be more effective. Effective Manned–Unmanned Teaming can give the fighting forces an unsymmetric advantage.

Large conventional platforms are much more vulnerable because of immense progress of conventional missile systems and homing technologies but also because of Unmanned Systems in a swarm. The mine-warfare both on land and in sea will be re-defined and unmanned early warning and surveillance swarms will be key areas.

The command centres would need intelligent inferring engines that assimilate huge amount of data from hundreds of sensors from unmanned systems and present the comprehensible data to human commanders so that they take crucial decisions.

Induction of an innovative first of its kind system has a pioneer advantage as countermeasures for such systems would not exist and that will provide an unsymmetrical advantage to the pioneer. This is not a domain for a wait-and-watch mindset. Here, the creators and pioneers take all. The Autonomous Unmanned Battlefield Systems have unlimited possibilities waiting to be explored.

There is a need for setting up specialised development centres for Unmanned Battlefield Systems in each domain of operation. 'Unmanned-by-birth' will have different principles of design need to evolve as we build and test such systems. There is a need of synergy between academic researchers and design professionals especially in development of algorithms and software. It is prudent to emphasise that deterministic algorithms form the foundation while the AI-based algorithms emerge out of systematic learning process by computer and physical simulations. Robust algorithms form the backbone of unmanned battlefield operations especially in challenged environments. Finally, the final call will be by battle controlling human commanders based on their heuristics and intuition.

Notes

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