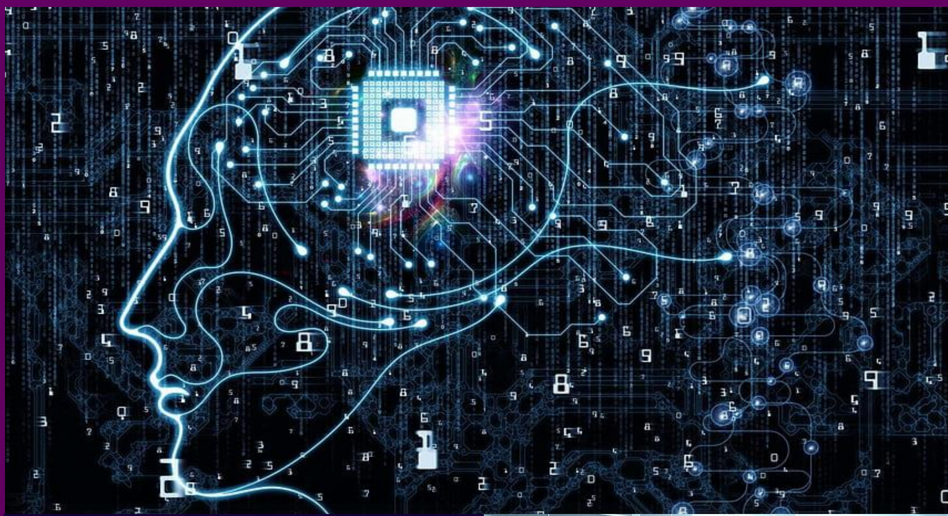
e-TACHYON

A TECHNOLOGY DIGEST

SEP 2022



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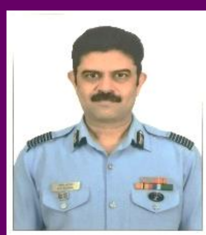

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EDITORIAL

1. e-TACHYON IS A BIANNUAL e-DIGEST WIDELY CIRCULATED THROUGH ELECTRONIC MEDIA, PUBLISHED BY AIR FORCE FACULTY AT MILIT. IT COVERS WIDE RANGE OF TOPICS RELATED TO MILITARY TECHNOLOGIES AND WARFARE INCLUDING EMERGING TRENDS IN STRATEGIC, OPERATIONAL AND TACTICAL ENVIRONMENT.

2. EXEMPLIFYING THE AFORESAID SAYING, AUTHORS OF ALL THE ARTICLES IN THIS ISSUE OF e-TACHYON, HAVE BRAVED ALL THE PREVALENT CHALLENGES TO ARRIVE AT MILIT FROM ACROSS THE LENGTH AND BREADTH OF THIS VAST NATION TO UNDERGO DSTSC (AF)-05. OUR PRESENT ISSUE IS A BALANCED MIX OF ARTICLES FROM VARIOUS TECHNOLOGICAL FIELD INFLUENCING BATTLEFIELDS OF PRESENT DAY AND THAT OF FUTURE.

3. THE MAGAZINE ENDEAVOURS TO BRING OUT THE LATENT CREATIVE SKILLS OF STUDENT OFFICERS AND HELPS THEM TO FORM THE HABIT OF READING AND WRITING. IT ALSO HELPS THEM TO HONE THEIR INTELLECTUAL SKILLS AS WELL AS BENEFITS IN WIDENING THE HORIZONS OF KNOWLEDGE. THIS GIVES A CHANCE TO THE OTHER STUDENT OFFICERS TO BE INSPIRED BY THEIR PEERS, EXPERIENCE.

4. THE ZEAL FOR LEARNING AMIDST ALL DIFFICULTIES AND THE ABILITY TO EMBRACE EMERGING TECHNOLOGIES IS AMPLY CLEAR FROM THE SELECTION OF PERTINENT TOPICS FOR ARTICLES.

HAPPY FLIPPINGS

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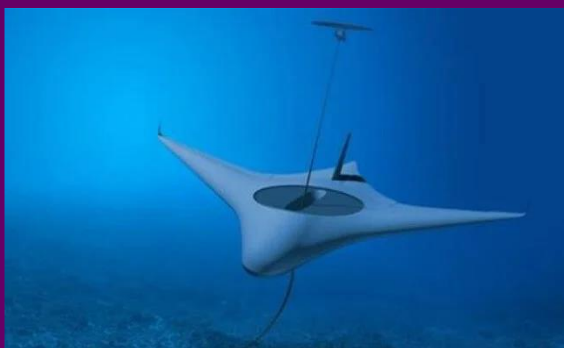

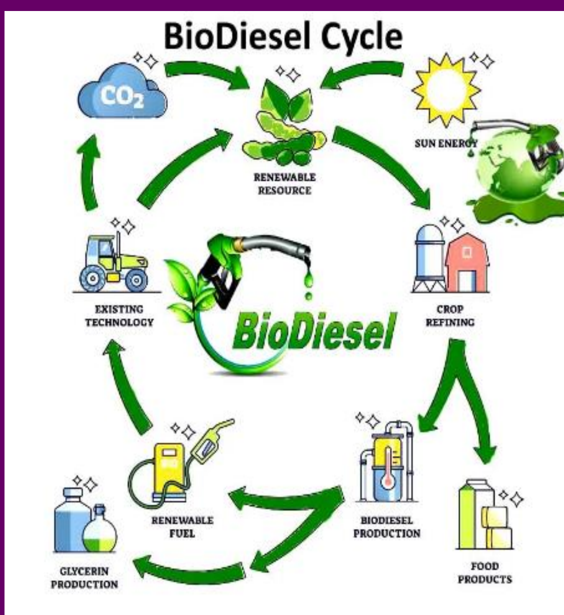

BioDiesel Cycle
CO_2
RENEWABLE RESOURCE
SUN ENERGY
EXISTING TECHNOLOGY
BioDiesel
CROP REFINING
RENEWABLE FUEL
BIODIESEL PRODUCTION
GLYCERIN PRODUCTION
FOOD PRODUCTS

GAME CHANGER BRAHMOS MISSILE FOR SU-30 MKIs

COMPILED BY
WG CDR ABHIJEET SINGH DSTSC(AF)-05

1. The Brahmos missile increases the combat range of the Su-30MKI, enabling the IAF to strike targets at long distances. For example, as part of a test in 2020, a Su-30 armed with the air-launched version of the missile took off from a base in Punjab and struck a target in the Indian Ocean.

2. The target was struck deep in the Indian Ocean, approximately 4,000 kilometres away, which was considered 'the longest' mission of this kind. The capability to hit targets far out in the Indian Ocean is essential for India, considering the increasing forays made by the Northern adversary in Indian Ocean Region.

3. The strategic location of the base would enable the IAF to employ its Su-30MKIs armed with BrahMos against targets near the strategic Malacca Strait, a narrow maritime chokepoint between Malaysia and Singapore that forms one of the gateways between the Indian Ocean and the Pacific Ocean, Also, if deployed on the Greater Nicobar Island, the Su-30 MKIs can strike targets in the vast swathes of the southern Indian Ocean.

4. Apart from that, the BrahMos armed Su-30s deployed on India's western and eastern border with Pakistan and China can take out targets inside those countries from stand-off ranges and in some cases, even from inside the Indian airspace. India's Defense Research and Development Organisation (DRDO) is also developing the smaller BrahMos-NG (next-generation) missile, which weighs around 1.5-ton and can be carried on unmodified Su-30MKI and other fighter jets like LCA-Tejas, Tejas MkII, AMCA and Rafale.

5. Furthermore, India has also developed the extended-range (ER) variant of the BrahMos missile, which reportedly has a range between 450-500 kilometres. There are further plans to extend the range of the missile up to 1,500 kilometers, which will bring the effective unrefuelled combat range of the BrahMos-armed Su-30MKIs to 4,500 kilometres (with 3000 km the range of Su-30 fighters). It is also important to note that if the range of the air launched BrahMos missile is increased up to 1500 kilometres, it will bring the IAF into the elite club of air forces in the world, such as that of the US and China. They already have long-range air-launched cruise missile capabilities.

6. The US Air Force has the AGM-158B Joint Air-to-Surface Standoff Missile-Extended Range (JASSM-ER) stealthy cruise missile, which is said to have a range of approximately 1000 kilometers. USAF F-15 Strike Eagle, with a range of 3,900 kilometers when armed with JASSM-ER cruise missiles, can hit targets up to 4,900 kilometers.

7. Compared to that, the Su-30MKI, with a range of 3000 kilometres, can hit targets at a slightly lesser range of 4500 kilometres when armed with the air-launched BrahMos missile with a range of 1500 kilometres.

8. That said, at present, the extended-range variant of BrahMos reportedly has a range of only 450-500 kilometres, which means the Su-30 can hit targets only up to 3500 kilometres. Meanwhile, China has Changjian–20 (CJ-20) Air-launched Cruise Missiles (ALCMs) that are said to have a range exceeding 2000 kilometres and are designed to be launched from the H-6K strategic bomber, which can carry up to six cruise missiles.

THE ENDLESS FLIGHT

COMPILED BY
WG CDR ANUPAM GUSAIN, DSTSC(AF)-05

1. Aircraft that can fly for months, without needing to land can be sent to carry out long term surveillance missions and could constantly monitor an area with high quality imagery. They could also be used to provide mobile and internet communication signals in remote areas, to support ground missions and even conduct long term research projects. All that is required to fuel such aircraft with Solar power.

2. What can make this possible today is a series of breakthroughs in lightweight materials, solar power batteries and autonomous navigation. Presently, the advances have come together to create planes that can fly day and night without intervention, potentially for months at a time.

3. Self-guided and self-powered planes started with NASA, which began working with the team behind the manned solar challenger plane that flew across the English Channel in 1981. By 1994, NASA pathfinder aircraft had demonstrated solar panels which were able to power aircraft to a high altitude. But the planes still needed a power source at night. Batteries that time were too heavy, so the NASA engineers turned to hydrogen fuel cells, which they integrated into their Helios prototype, aiming to demonstrate round the clock operation.

4. Unfortunately, the Helios proved structurally fragile and broke up dramatically on a test flight in 2003 after encountering turbulence, marking the end of NASA's pursuit of solar powered drones. The efficiency of the solar panels used on the planes today is not significantly different from those used for the earlier. What's improved considerably are the weight and robustness of the panels, as well as the cost. Amorphous silicon cells are lighter and more flexible and contribute to a more reliable structure that needs less power to propel it.

5. Other advances include the artificial intelligence that guides the aircraft, sensors that gather data on the surrounding and continually changing weather and the carbon fiber composites used to build the plane. The result of these technologies is a plane that can do things previously only possible with satellites, but that can fly continuously over one area rather than having to orbit the entire globe. Unlike with satellites, it's possible to land and repair the aircraft if something goes wrong.

6. The challenge now for the engineers working on solar-powered drones is to increase the amount of power they can collect and store and validate how long the batteries can stand constant charging and discharging. This will enable them to provide higher bandwidth communication and sustain flights in higher latitudes and during the winter months.

AIR POWER IN THE AI ERA

COMPILED BY
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INTRODUCTION

1. In the journey of its development, air power will be delivered by a system that combines AI and machines in the near future. Even if complete autonomy remains a futuristic concept for some more time, it is certain that fully autonomous systems in the war fighting arena will become reality. The improvements with AI will originate right from the strategic level, followed by a cascading effect of the changes in the conduct of air campaign and tactical appreciation of operations. Although, it is at the operational level that the induction of AI will create the maximum visible effect, its impact will be felt in all aspects of air power from its conceptualization, generation, application and sustainment.

2. Although for the time being it is accepted that AI has not matured enough and therefore IAF has not factored in the attributes of AI into its doctrine currently. However, IAF needs to start analysing and investigate the fundamental changes to be made in the doctrine for accommodating the altered capabilities expected to come with the advent of AI.

IMPLICATIONS OF AI ON AIR POWER AND OODA LOOP

3. The potential uses of AI in revolutionizing airpower operations range from tactical to the strategic level. Sensors and perceivers collect or create data which must be then stored, filtered and structured. Processing turns collected raw data into usable AI inputs. Algorithms can then create models, develop and test insights, draw correlations and detect anomalies for human decision-makers or actors. AI systems will be capable to streamline command and control and decision-making processes in every step of the Observe-Orient-Decide-Act (OODA) loop. This will be achieved by collecting, processing and translating data into a unified situational awareness view, while providing options for a recommended course of actions. This will ultimately help the operators in the act phase of the loop. The observation, orientation and decision loops can be tightened by automating the human-intensive tasks inside the targeting cycle. The Future required AI roles and functions to each of the OODA steps are as follows: -

(a) **Observe (Sensing)**. It will include data collection from a broad array of sensors, including social media analysis and other forms of structured and unstructured data collection, data verification and fusing it into a unified view.

This requires a robust, interoperable, IT infrastructure capable of rapidly handling large amounts of data and multiple security levels.

(b) **<u>Orient (Situational Understanding)</u>**. It will include applying big data analytics and algorithms for data processing, data presentation for timely abstraction and reasoning based on condensed unified view rich enough to provide the required level of detail. This should include graphical displays of the situation, timelines, capabilities, resources and effects.

(c) **<u>Decide (Plan Generation)</u>**. A timely and condensed view of the situation will be presented along with probable adversary courses of action and recommendation of own courses of action. It will also include advice on potential consequences of the actions taken. To this end, it must be made possible to assess and validate the reliability of the AI to ensure predictable and explainable outcomes allowing the human to properly trust the system.

(d) **<u>Act</u>**. As AI gets more advanced and with the increase in time pressure, the human may only be requested to approve a pre-programmed action, or systems will take fully autonomous decisions. In order to prevent erroneous and unwanted decisions, AI for such systems must have stringent requirements. Moreover, for the actions performed by such systems, the legal and ethical responsibility will be of the humans. A number of issues will arise. For example, would it be legal or ethical for a machine to kill a human being and for a human to destroy a machine? Would it be permissible for a machine to neutralise a human inhabited centre identified as a centre of gravity? While it is not possible to predict the direction of the changes that will take place, but it is certain that the conduct and characteristics of war will change and become much more complex.

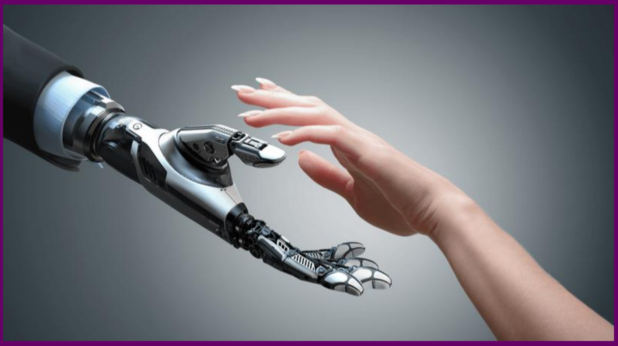
EMPLOYMENT OF AIR POWER IN FUTURE

4. With increase in acceptability of AI in the decision-making cycle of airborne systems, it is necessary to examine the probable changes that could take place in the employment of air power in the future. The following major changes are likely to take place when AI will be fully accepted into the OODA loop: -

(a) **<u>Target Recognition and Targeting</u>**. The second change would be the target recognition, selection and engagement process would be autonomous.

In the future, the autonomous recognition, selection and engagement of targets would be accepted as a standard operating procedure.

(b) **Human-Machine Integration**. First, air power will be delivered, across all its roles, through human-machine integrated mission packages. A human-machine integrated package would mean that some elements within the package would be AI-operated systems with autonomous liberty while some others will be manned systems or with a 'human-in-the-loop'. AI may operate without human oversight if it is reliably accurate and operates in a relatively low-risk area. To help this decision, many types of AI can express confidence levels with their predictions. If the training data was insufficient, or the AI does not know how to interpret the input data, the confidence may be low. The AI confidence level and accuracy can be compared with humans or other models to decide how much authority to delegate to AI, which may be dependent on the situation.



(c) **Airspace Management**. AI could be employed for autonomous airspace management which will facilitate a seamless interface of separate civil and military airspace as well as the control mechanisms. It is possible that in the near future, autonomous aerial vehicles will be controlled by autonomous airspace management agents. From a purely human understanding point of view, such a situation of machines controlling machines without direct human oversight may not be acceptable as of now.

(d) **Combat Search and Rescue Operations**. The fourth change, which could be one of the earlier changes that could be facilitated by the induction of AI into air operations, is the role of CSR. The advantages of employing AI to conduct this critical role, especially in times of hostilities, is that own combatants are not placed at risk in attempting to rescue the injured or other combatants in trouble.

HUMAN-MACHINE TEAMING

5. One of the key innovations which will pave the way to future airpower is the concept of human-machine teaming, also known as manned-unmanned teaming (MUM-T). It is the operation of manned and unmanned assets in concert towards a shared mission objective. This concept is deemed to be a critical capability for future military operations in all domains. Some nations are currently testing and implementing diverse configurations to improve pilots' safety, situational awareness, decision-making and mission effectiveness in military aviation using this concept. The three different models of this concept are as follows: -

(a) **Loyal Wingman**. The US Air Force Research Laboratory has been working on the 'Loyal Wingman' model, where a manned command aircraft pairs with an unmanned off-board aircraft serving as a wingman or scout. In 2015, a modified unmanned F-16 was paired with a manned F-16 in formation flight in a live demonstration. During a demonstration in 2017, the pilotless F-16 broke off from the formation, attacked simulated targets on the ground, modified its flight pattern in response to mock threats and other changing environmental conditions and re-entered formation with the manned aircraft. USAF planning foresees future applications pairing a manned F-35 Joint Strike Fighter with such an unmanned wingman.

(b) **Flocking**. The next technology waypoint with a more demanding AI requirement would be 'Flocking'. This is distinct from the 'Loyal Wingman' concept in that a discernible number of unmanned aircraft in a flock execute more abstract commander's intent, while the command aircraft no longer exercises direct control over single aircraft in the flock. However, the command aircraft can still identify discrete elements of the formation and command discrete effects from the individual asset.

(c) **Swarming**. The third model, 'Swarming', exceeds the complexity of flocking, so that an operator cannot know the position or individual actions of any discrete swarm element and must command the swarm in the aggregate. In turn, the swarm elements will complete the bulk of the combat work. There are a multitude of uses for such drone swarms, including reconnaissance and surveillance, locating and pursuing targets, or conducting electronic warfare measures. Furthermore, the swarm could act as expendable decoys to spoof enemy air defence by pretending to be much larger targets.

CHALLENGES AND CONCLUSION

6. New AI technologies not only have potential benefits, but also shortcomings and risks that need to be assessed and mitigated as necessary. There is a range of complex

technological, organisational and operational challenges which will be faced while integrating AI systems into airpower platforms and systems, to transform computers from tools into problem-solving thinking machines.

7. One of the challenges in AI is its nature which makes it hard to predict its behaviour. Due to the rapid shift in the environment in warfare, AI systems have to work in a context that is highly unstructured and unpredictable. There will be opponents in the warfare that deliberately try to disrupt or deceive the AI systems. So, if human operators are not aware what AI will do in a given situation, it could complicate planning as well as make operations more difficult and accidents more likely.

8. Another challenge and most importantly the critical question is how much we can trust AI systems, particularly in the areas of safety-critical systems? Furthermore, a growing field of research is adversarial machine learning which focuses on how to deceive AI systems into making wrong predictions by generating false data. Both state and non-state actors may use adversarial machine learning to deceive opposing sides, using incorrect data to generate wrong conclusions and in doing so, alter the decision-making processes. The adversarial machine learning might have a huge disruptive impact as compared to the benefits gained from the technology.

9. Apart from linking together technologically, many of these complex AI systems also need to be linked together organizationally and operationally. This is an ongoing and a complex challenge for many air forces currently. The challenge is to effectively and in real-time integrate the AI-enabled sensor-to-shooter loops and data streams between the various services and platforms.

USE OF AI FOR PREDICTING THUNDERSTORM ACTIVITY

COMPILED BY
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INTRODUCTION

1. As per National Transportation Safety Board (NTSB), Thunderstorm accounts for 18% of fatal general aviation accidents. Importance of timely prediction of Thunderstorm needs no emphasis, especially in aviation. However, because of the size of the phenomenon in both spatial and temporal scales, predicting Thunderstorm accurately is a challenge even today. Thunderstorm activity can be associated with big organized systems, like; tropical storms, etc or it can be a localized phenomenon. While it is generally easy to predict the thunderstorms associated with organized big weather systems, prediction of localised insitu developed thunderstorms is really challenging.

2. Numerical Weather Prediction (NWP) models have become mainstay of weather prediction in today's world. Weather forecasts are generated by some of the world's most sophisticated computers. Predicting weather is a very complex and volatile phenomenon that requires a great amount of money, data and time to evaluate. Higher the resolution of the model higher is the computational power required. Despite the highest possible resolutions, thunderstorm prediction is sometimes not accurate. The future may follow a very different path regarding weather forecasting and that future is Artificial Intelligence.

PRESENT SYSTEM OF WEATHER FORECASTING

3. Presently, Numerical Weather Prediction (NWP) is the mainstay of weather forecasting world over. NWP uses super computers to process huge volumes of oceanic and atmospheric data. This data is aggregated from weather stations and integrate it with data from other sources like, buoys and weather trackers. Such huge volumes of data so collected is then analysed using NWP models that simulate the physics of fluid dynamics in weather, which takes a significant amount of processing power, hours to finish and a significant amount of money to collect and process. In the current day, the joint demand for speed and accuracy in a prediction puts even the most sophisticated weather algorithms to the test.

4. Weather monitors in observatories, on the land and in the waters provide a flood of climate and weather data all around the world. It is simply too big and complex

for humans or even standard computer networks to analyse and scan for similarities and that is an issue because it is a waste of time and storage if this cascade of data is unable to be fully analysed. Since pattern-recognition skills in Artificial Intelligence (AI) are tailor-made for such a job, researchers are using machine learning, neural networks, and deep learning to do this. Enormous quantities of data may be put into the algorithms, which can then learn how and when to detect a storm that could produce lightning or tornadoes. It detects trends that might lead to catastrophic tropical storms or severe thunderstorms.

AI FOR PREDICTING THUNDERSTORM

5. A collaboration of studies between the University of Washington and Microsoft Research demonstrates how artificial intelligence can study previous climate patterns to forecast events in the future more quickly and almost as accurately as current technologies. Instead of complex physics computations, the newly created global weather model based its forecasts on the last 40 years of weather information. This design is less effective than today's best conventional forecasting models, it requires 7,000 times less computer power to produce projections for the same number of spots on the entire planet. This decreased computer labour leads to faster weather forecasts. These faster forecasts would enable weather forecasters to run many models with marginally varied starting conditions. This weather forecasting approach is known as "ensemble forecasting" which allows forecasters to encompass the range of possible outcomes for a meteorological event, such as where a thunderstorm may impact. After training on previous weather information, the AI system is capable of generating connections among parameters that physics models just cannot. We can utilize a lot fewer variables and create a model that is considerably quicker as a result.

The researchers overlaid six sides of a cube over the entire planet to combine effective AI approaches with weather prediction. Finally, like with an architectural print design, they smoothed down the cube's six faces. Because of the poles' particular significance in the climate, the researchers handled the polar faces uniquely to enhance prediction accuracy.

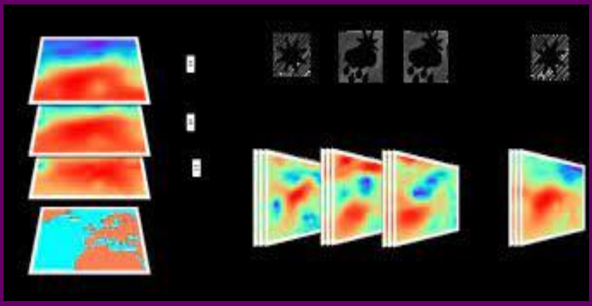
6. Compared to the old methodology of weather forecasting, which takes 3 hours and costs €30 million in computer hardware to complete, Deep Weather's novel method of weather forecasting has already been shown to be both quicker and cheaper. Deep Weather, using a computer that costs €10,000, can make the same forecast in 100 milliseconds, which would be a significant increase. By employing linear regression techniques to analyse more complicated data in a shorter amount of time, meteorologists may now make more accurate predictions of thunderstorms.

7. Present day Numerical Weather Prediction models are good at providing area guidance. The positioning and timing of the thunderstorms cannot be predicted accurately. To provide short-term weather predictions, the AI model examines and tries to manipulate huge data sets transmitted from weather satellites, signal repeaters and radiosondes. Artificial Neural Networks, Group Neural Networks, Backpropagation Networks, Radial Basis Networks, General Regression Neural Networks, Genetic Algorithms, Multilayer Perceptron and Fuzzy Clustering are some AI approaches for weather forecasting. A CNN is a series of stages of mathematical processes. It accepts satellite imagery as input and converts it to outgoing pictures. This U-Net architecture is made up of two convolutional neural networks, the second of which works in reverse in an encoding-decoding process.

FORECASTING USING A CONVOLUTIONAL NEURAL NETWORK

8. The Deep Learning Weather Prediction (DLWP) is one of the weather models that use a UNET CNN. It takes initial atmospheric states as inputs and predicts the state of the atmosphere at a given future time. The model takes historical data of weather patterns that are fed to the network in the training phase. The weather predictions are achieved in three steps.

9. In the first step, the researchers map the predictions using a "Cubed Sphere Approach," where the Earth is bounded into six faces of a cube. This cube is then flattened, which allows the researchers to focus on one cube face at a time.



10. In the second step, the researchers focus on the architecture of the neural network. It uses filters to extract features from the input data. The image in the first network is down sampled, resulting in fewer parameters in the network and the image is up sampled in the second network, so it comes back to its original size. Certain layers in the model are skipped and the outputs of some layers are fed as inputs to other layers.

11. These predictions are stabilized in medium to long-term using sequence prediction techniques. This sequence prediction technique above will yield a 6-hour forecast and 12-hour forecast, as the input of the current time and the current time minus 6 hours are fed into the architecture. The model improves upon itself by calculating the mean square error of the differences between the actual data at each time and the forecast it predicts for the same time.

CONCLUSION

12. Catastrophic effects of thunderstorm on aviation are well known. Thunderstorm predominantly being a localised phenomenon, cannot be predicted accurately using conventional numerical weather prediction models. Forecaster needs to apply his skill and use his experience to predict thunderstorms accurately.

COUNTERING ROGUE DRONES AND DRONE SWARMS

COMPILED BY
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INTRODUCTION

1. On Sept 14, 2019, a drone cum missile attack was carried out on the Aramco refineries at Abqaiq and Khurais in Saudi Arabia. The drones were apparently launched from the Iranian air base at Ahvaz and flew around 640 km crossing through Kuwaiti air space. The drones were delta winged aircraft that possibly used optical guidance instead of GPS. Notably the Saudis had installed state of art air defense systems, which apparently failed to detect and engage. Whatever be the truth, it remains clear that small, low-cost systems were able to outwit multi-million-dollar, state of art systems. Conversely, had the Patriots engaged the drones, the dichotomy of a 3m$ missile taking on a 2000$ drone would have shown up starkly. The drones and missiles reportedly came in at low altitudes at which the anti-aircraft radar installed for detecting high flying aircraft and missiles, was unable to pick them up. With this as a backdrop, the question arises, what should India do as far as the drone threat is concerned.

2. Due to the technological challenges associated with detecting a largely non-metallic object and the fast-changing technologies associated with drones, there is no single system that can provide a failsafe protection against rogue drones. The threat being considered, is not from the high-flying armed drones like the Predators, Reapers and Global Hawks, but from the small weaponized drones that may be assembled in garages or at home.

HOW DRONES WORK?

3. Most drones essentially require command radio signals coming from a ground station in the hands of a pilot, while GPS is used for guidance. The onboard vitals include the radio receiver, GPS sensor, the camera plus other components. While one would typically seek to disrupt the command or GPS signals, or even to blind the camera in order to prevent the drone from achieving its objective, the paradox is that drones can operate without radio command signals and in the absence of GPS feed, as well.

DRONE DETECTION

4. Before one can intercept a drone, it needs to be detected, tracked and classified in much the same way as an anti-aircraft or missile system would operate. Drones, however present some tactical and technological challenges that need to be understood

and overcome. The first challenge is that a drone attack can be launched from any direction, which makes a 360-degree surveillance inescapable. Further, drones by nature are small, low flying objects with very few metal parts, so detection by radar is difficult at longer ranges. Further, while radar may operate satisfactorily in open areas, in built up areas, it presents the problem of reflection from tall buildings. On the other hand, a low flying drone may find it easy to hide itself in ground clutter. While FMCW radars can detect moving objects and may be useful in picking up drones especially as their propellers constitute a significant speed differential, these radars on the other hand, are limited in range. Therefore, while radar is essential, we need something in addition to radar.

5. Another detection option is heat sensing which can be done either by thermal or IR detector. Both have their pros and cons - IR sensors have a limited range as they require near infra-red energy bouncing off the object to be picked up. Thermal cameras work well at night as they sense temperature differences. While thermal cameras can work during the day as well, the image produced of a drone against the sky, particularly in hot areas may not be suitable for tracking and identification in a security scenario. The thermal image would have to be suitably processed before it can be used for day-time tracking. In addition to the radar, one would need an optical sensor providing day and night surveillance. The radar would provide 360 cover and early warning, while the Electro Optic (EO) system would provide a useful back up. However, neither the radar nor the EO would be capable of picking up the radio command signals.

6. In order to pick up the radio signals being exchanged between UAV and pilot, RF sensors would be required. These are radio receivers that detect signals in the 2.4 and 5.8 GHZ frequencies, that are used exclusively by drones. The limitation here is that the RF sensors would be unable to pick up pre-programmed drones flying autonomously without the help of radio command guidance. Further, RF sensors would not be able to provide directional and range information directly. Acoustic sensors are also available, but these are limited in their range and are less effective in noisy environments. Therefore, it is clear that a mix of technologies would be required for effective drone detection, which would also depend upon the type of threat and the area to be protected. Further, a layered defence would be required where in a typical case, detection should ideally be at a range of 3 to 5 km, tracking and classification at 1 to 3 km and prosecution from 500 m to 800 m.

HARD AND SOFT KILL OPTIONS

7. The options for prosecuting hostile drones are traditionally divided into soft kills and hard kills. Soft kills are those where the command signal is interrupted, or, where the GPS signal is spoofed to take control of the drone. The problem is that today's drones can avoid using both radio commands and GPS. Hard kills are those where projectiles or kinetics are used to disable and bring down the drones. Jamming is one of the most common anti drone soft kill methods, but the issue is that jamming is illegal in India as well. The limitations of jamming, apart from the legal angle, are that it is limited in range and will affect other receivers as well. In some areas, especially near airports, jamming may not be a good idea as it could disrupt vital communications. Further, the handheld jammer, which may be adequate for guarding a tactical position in the military context, may not be suitable when there is a large facility or a group of targets to be protected, as it will be simply impractical to position men permanently on rooftops with handheld jammers. Similarly, it may be inadequate against multiple drones. Hence, while handheld jammers are needed, what is also needed is an automated response system that can handle multiple drone targets simultaneously.

8. Since jamming will not be effective against autonomous drones, spoofing of the GPS signal would be the next option. The spoofed signal would then direct the rogue drone to a safe location where it could be dealt with. But with miniature onboard gyros and inertial navigation systems, a drone may use dead reckoning to navigate, eliminating GPS altogether. What if, the drone operates in autonomous mode (no RF), and using inertial guidance (no GPS)? It is here that we need to get imaginative. Apparently in the Saudi attack, the drones had used optical guidance.

9. One possibility is to carry out a cyber-attack to target the apps that most commercial drones use. For instance, a set of pre-packaged exploits could target the wireless protocols and the operating systems being used. Similarly, the app being used for telemetry between a drone and a mobile phone device could also be targeted, or if there is a communications link between the drone and the manufacturer's server, that could be another possibility.

10. The possibilities in hard Kill options are: -

(a) A laser system using a 30-kilowatt spectral beam combining fiber laser, in which multiple fiber laser modules form a single, powerful, high-quality beam, that scales to higher or lower power levels. The energy stream is concentrated and aimed at the target. The laser beam applies intense heat that dazzles, damages or destroys the threat. Although not declared, it is believed that during demonstrations, the targets were at a range of about 1.6 Km.

(b) High Power Microwave are devices that generate an Electromagnetic Pulse (EMP) capable of disrupting electronic devices. The EMP interferes with radio links and disrupts or even destroys the electronic circuitry in drones (plus any other electronic device within range) due to the damaging voltage and currents it creates. Both these methods are effective, short-range weapons, but entail high cost, requiring large set ups and are capable of collateral damage.

NETS & NET GUNS

11. This involves firing a net at a drone or otherwise bringing a net into contact with the rotors that effectively stops the drone. This can be done in three ways:

(a) Net Cannon fired from the ground, anywhere from 20m to 300m effectiveness. Can be used with or without a parachute for controlled descent of the captured drone.

(b) Net cannon fired from another drone: This overcomes the limited range of a net cannon on the ground. Can be difficult to capture another moving drone. Normally used with a parachute for controlled descent of the captured drone.

(c) Hanging net deployed from a 'net drone'. The drone is captured by manoeuvring the friendly net carrying drone towards the rogue drone.

DRONE AGAINST DRONE

12. A US based company has developed a fast drone capable of engaging hostile drones. As soon as a hostile UAV passes over the perimeter of an airspace, the defender drone launches into the sky at around 114 Kmph, locks onto the enemy drone and fires a net to trap and tow the drone away. However, it has only two shots, which make it ineffective against multiple drones.

DRONE SWARMS

13. The main inspiration for drone swarms comes from the observation of animal societies, like insects, winged animals and fish, that exhibit a collective intelligence to achieve complex goals through simple rules and local interactions. The main benefits of a drone swarm includes robustness, scalability, and flexibility (the capability to manage a broad spectrum of different environments and tasks). Unlike animal societies, drone swarms may include drones of different types but incorporate both large and small drones equipped with different payloads. The coordinated drone swarm could be also considered as single array of sensors configured to measure of a host of environmental parameters. Drones within the swarm may serve different roles based on their different capabilities. Each individual of the swarm acts with a certain level of autonomy; performs only local sensing and communication operates without centralized control or global knowledge and cooperates to achieve a global task.

14. If the full technological potential of drone swarms is to be unlocked, there are four main areas of work: determining swarm size, diversity, customization and hardening. The swarm size is in general decided by the mission. As a thumb rule, the greater the swarm size, the more capable the swarm. Larger swarms can better survive some defence as the loss of a few members will have only minimal effect. Further, more inputs will mean more information that could affect the swarm's behaviour. This would mean handling ever larger amounts of data, which poses its own problems of complexity and memory size. Also, larger swarms are more likely to be detected. Diversity implies that drone swarms could also include drones working in different dimensions eg, flying drones could work in cooperation with land drones. Drones within the swarm may serve different roles based on their different capabilities. Attack drones carry out strikes against targets, while sensor drones collect information about the environment to inform other drones and communication drones ensure the integrity of inter-swarm communication. A drone swarm could incorporate attack drones of different sizes, optimized for different types of targets.

COUNTERING DRONE SWARMS

15. Drone swarming creates significant vulnerabilities to electronic warfare protecting against this vulnerability is critical. Drone swarm functioning inherently depends on the ability of the drones to communicate with another. If the drones cannot share information due to jamming, the drone swarm cannot function as a coherent whole. Hence, development of new communication protocols capable of resisting electronic warfare will be required. The key to efficient cooperative functioning is effective communication and the key to countering a drone swarm is denial of communication and information to its sensors. Similarly, feeding of false signals to the sensors of a swarm could be another method of countering swarms. Individual elements only communicate with one another taking their cues from the other's behaviour. If the cues stop coming, as when there are not enough drones left to communicate, the swarm could disintegrate.

16. Drone swarms offer significant advantages in each dimension i.e. land, sea and air. For instance, the US Navy is understood to be developing autonomous drone boat swarm capability, as well as undersea submarine hunters. The US Marine Corps has successfully tested small swarms for infantry to carry out strikes and electronic warfare attacks while the USAF is using them to suppress enemy air defences. Every counter measure has its uses and its limitations and there is a full-fledged industry working to overcome the existing defensive measures. Drones are the future of warfare and a concerted collaborative effort of all stake holders will be needed to meet this threat. Failure to do so, will plant us on the wrong side of the power of the swarm.

DETECTING HYPERSONIC WEAPONS

COMPILED BY
WG CDR NITIN KUMAR DSTSC(AF)-05

INTRODUCTION

1. Contemporary times are seeing rising tensions between the USA (with its zero-sum-gain policies, Russia (with its aggressive behaviour toward its neighbours) and China (with its ever increasing military and economic status). This has led to immense competition among these nations which has taken many forms such as Trade wars, alliances and propaganda campaigns etc. The military competition is also very intense with each side trying to improve its weapons and capabilities. Among these capabilities is new high-speed projectiles that these countries are developing hypersonic vehicles. These countries are also looking at ways to counter these threats which starts with detection and tracking. India, having close proximity and stress relations with China, cannot afford to lag behind. India has its own hypersonic weapons program, though at nascent stage. But it also needs to address the issue of countering the hypersonic threat by ensuring early detection and tracking, during all phases of flight.

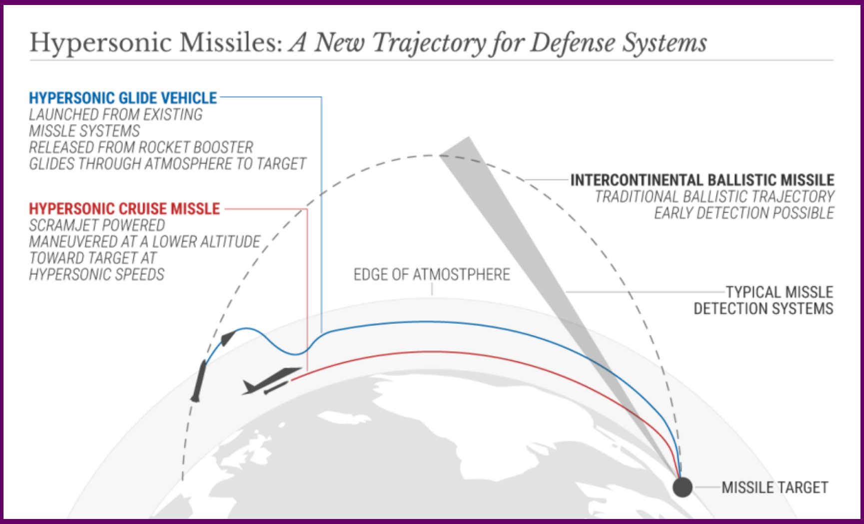
HYPERSONIC WEAPONS

2. A supersonic vehicle flies above the speed of sound (around 1000km/h or 650 knots), but a hypersonic one flies above Mach 5. It is not only the speed that makes hypersonic dangerous as ballistic missiles routinely achieve speeds of up to Mach 25. The lethality of hypersonic is in the combination of speed and manoeuvrability which makes them extremely difficult to defend against and leads to compressed engagement timelines against elusive targets. Hypersonic is an umbrella term that covers two different technologies hypersonic cruise missiles and boost-glide systems.

PROPOSAL

3. Since, radars are limited by the curvature of the Earth and provide only a limited warning time, it is only obvious that a space-based solution is sought. India should embark on a space-based defence system for detecting and tracking hypersonic weapons and glide vehicles. A constellation of satellites with sensitive Thermal/EOIR sensors onboard has been proposed to track these threats during all phases of the flight. The detection of launches using IR sensors has already been proved. The system should also calculate (using thermal signatures at various stages of flight and artificial intelligence) Impact Point (IP) of these weapons.

This is important in order to activate correct interceptor system which is located nearest to the intended impact point. The satellites should be Low Earth Orbit (LEO) so that accurate tracking can be carried out and visibility/detection till lower layers of earth atmosphere is possible. Such a system will facilitate deterrence to China and prevent exploitation of gap in capability. India already has the in-house capability in manufacturing and launching satellites. However, the number of satellites is dependent on the ability of the sensors to penetrate the lowest layers of the atmosphere while maintaining sufficient sensitivity, which means that sensor performance will be the cornerstone of such hypersonic missile detection system.



CONCLUSION

4. With China rapidly increasing its military capabilities, it is imperative for India to always think ahead and develop solutions so that credible deterrence is always achieved with respect to China. With hypersonic weapons being touted as the next game changer in strategic military domain, it is important for India to be alert and responsive towards this threat.

HYPERSONIC MISSILES COUNTERMEASURES

COMPILED BY
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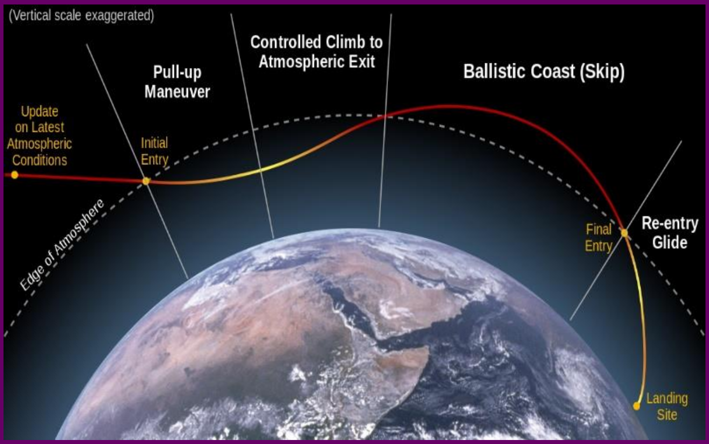
BACKGROUND

1. The Russia Ukraine war has been at the centre stage of global affairs since quite a few months. The Russian invasion of Ukraine is the largest conflict that Europe has seen after World War II. Air strikes, rocket and artillery bombardment, extensive usage of drones and latest technology, missile attack on warship are the key highlights of this long drawn conflict. The most remarkable chapter in this conflict is the demonstration of hypersonic missile technology. Russia successfully test fired Zircon missile from Barents Sea which hit a target in White Sea, this dimension has given rise to hypersonic arms race. Hypersonic missiles are capable of maneuvering during flight which makes them difficult to track and defeat. This article elaborates on efforts towards building of countermeasures against hypersonic missiles.

HYPERSONIC MISSILES

2. Broadly hypersonic missiles are the one which can travel at Mach 5, five times the speed of the sound. Apart from speed, altitude of flight and maneuverability makes hypersonic missile difficult to track. Ballistic missiles as well attain hypersonic speed as they re-enter atmosphere. Unlike ballistic missiles hypersonic missile possess the ability to maneuver at high speed. The altitude of hypersonic missiles is between 20 km to 60 km. The combined characteristics of high speed, low altitude and high maneuverability make hypersonic weapons attractive.

(a) **Hypersonic Flight**. Ballistic re-entry vehicles travel through vacuum of the space and upon re-entering the atmosphere they experience certain aerodynamic and thermal phenomenon that are not common to subsonic or supersonic conditions. But hypersonic missiles face aerothermal conditions throughout flight. Extreme temperatures and high flow friction these two phenomena are observed only during hypersonic flight. Ionization of surrounding gases and formation of plasma is the manifestation of previously mentioned phenomenon.



(b) **Hypersonic Cruise Missile and Hypersonic Glide Vehicle.** Hypersonic Cruise Missile uses on board propulsion in terms of Supersonic Combustion Ramjet. Like other cruise missiles HCM remains powered throughout the flight. While HCM are advantageous in terms of weight, packing and efficiency scramjet's sensitivity to disturbances in air flow often limit its ability to maneuver. Hypersonic Glide Vehicle (HGV) it has detachable booster to accelerate it to near space region. HGV does not travel in space region instead it re-enters atmosphere at high speed. The shape of the airframe enables HGV to reduce drag and produce lift. This way HGV can glide through the atmosphere. HGV being unpowered once the booster is detached, it gradually reduces the speed.

VULNERABILITIES OF HYPERSONIC MISSILES

3. Hypersonic after re-entering the atmosphere experience temperature as high as 4000 degree Fahrenheit. In such an environment vehicle's surrounding atmosphere dissociates into plasma. Ballistic re-entry vehicles experience similar conditions for tens of seconds while entering atmosphere. Whereas hypersonic weapons must survive similar conditions for few minutes. The immediate effect of high temperature is in terms of disruptions in scramjet functioning. It can also be proposed that Infra-Red signature of hypersonic missiles is higher than subsonic or supersonic weapons.

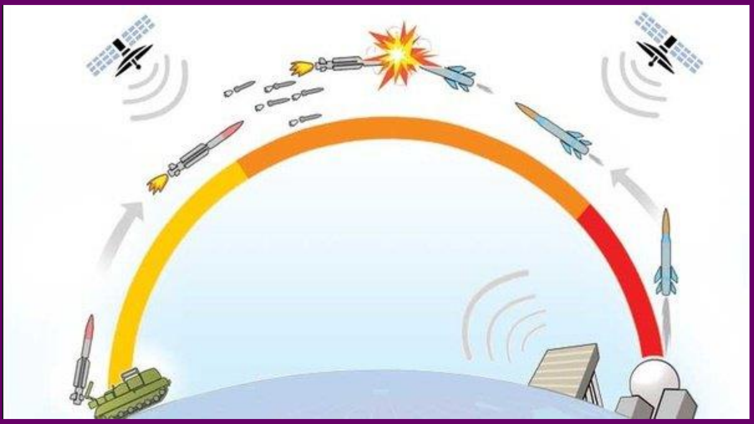
4. Hypersonic gliders expend energies while performing manoeuvres. The energy expended during maneuvers can be exploited to form defence against hypersonic missiles. Boundary level transition is the phenomenon in which due to change in speed of hypersonic vehicle laminar body layer flow becomes turbulent where air follows a chaotic path over the vehicle. This leads to high heat and vibration loads on the surface. The generation of boundary level transition can be a way ahead towards building hypersonic defenses.

SENSING MECHANISM

5. Current surface based radars can only track hypersonic weapons in the last phase of flight. Space based sensors can track the entire trajectory of the hypersonic missiles. With this capability interception is easier and attack on hypersonic vehicle is also possible. Under Defence Support Program USA has planted missile early warning system in geosynchronous orbit. This system can detect booster boom in the initial phase but may lack the sensitivity to track targets through the glide phase. Missile Defence Agency and Space Development Agency of USA has developed a tracking layer providing wide field of view sensor satellites for launch indication. These satellites are in design phase right now. Once deployed they can produce low latency fire control quality data.

INTERCEPTOR DEVELOPMENT

6. Missile interceptors engage ballistic missile in exo-atmospheric flight. Hypersonic missiles with their glide path in endo atmospheric region remain beneath the tracking horizons of surface based radars. Even if radar tracks hypersonic missiles currently no midcourse interceptor works in endo atmospheric conditions. With the available technology hypersonic missiles can be engaged only during its final phase of the flight. Hypersonic missiles in their glide phase maneuver significantly less to conserve energy. New long range interceptors are required to engage the missile during its glide path. A long range interceptor missile linked with space sensor can hit hypersonic targets with better kill probability. Command Control Battle Management and Communications system (C2BMC) is used in ballistic missile Defence. The system with adequate upgradation can be used for hypersonic detection and warning.



THE GLOBAL SCENARIO

7. China is developing an early warning system. Artificial Intelligence based model would collect all the data during initial phase of hypersonic glide vehicle and it will predict HGV's trajectory. Various deep learning algorithms are used to eliminate noise from the received signals. The system has been proved for HGVs travelling up to the speed of 12 Mach. With advent in hypersonic countermeasures USA and China are locked in hypersonic tit for tat. While global powers are hell bound on building hypersonic missile countermeasures India is at developmental stage of first hypersonic missile Brahmos II. Hypersonic Missile Defence System is still a distant dream for India.

LASER IN MILITARY

COMPILED BY
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INTRODUCTION

1. The idea of using light as a weapon can be traced back to Archimedes. In the second century AD, the author Lucian wrote that during the siege of Syracuse (214-212 BC Archimedes destroyed the enemy ships with fire. He may have used mirrors acting collectively as a parabolic reflector to burn the Roman ships attacking Syracuse. At the dawn of laser technology, French physicist Louis des Brailles said, “The laser has a great future. It is difficult to predict where and how it will find its application, however, I think that it is a whole new age of technology.” The laser has moved in 58 years from “a solution looking for a problem” to a key technology that contributes to major sectors of the world economy. Laser devices are the core technology in instruments performing vital functions in many industries including transportation, healthcare and telecommunications. However, Laser is not only used for weapon applications, but it have many other technical applications too such as for the alignment process or in the measuring instrumentation and calibration to name a few.

DIRECTLY AS AN ENERGY WEAPON

2. Directed energy weapons are being developed, such as Boeing’s Airborne Laser which was constructed inside a Boeing 747. Designated the YAL-1, it is intended to kill short-and intermediate-range ballistic missiles in their boost phase.

DEFENSIVE COUNTERMEASURES

3. Defensive countermeasure applications can range from compact, low power infrared countermeasures to high power, airborne laser systems. IR countermeasure systems use lasers to confuse the seeker heads on heat-seeking anti-aircraft missiles. High power boost-phase intercept laser systems use a complex system of lasers to find, track and destroy intercontinental ballistic missiles (ICBM). In this type of system, a chemical laser, one in which the laser operation is powered by an energetic chemical reaction, is used as the main weapon beam. The Mobile Tactical High-Energy Laser (MTHEL) is another defensive laser system under development; this is envisioned as a field-deployable weapon system able to track incoming artillery projectiles and cruise missiles by radar and destroy them with a powerful deuterium fluoride laser.

TARGET DESIGNATOR

4. Another military use of lasers is as a laser target designator. This is a low-power laser pointer used to indicate a target for a precision-guided munition, typically launched from an aircraft. The guided munition adjusts its flightpath to home into the laser light reflected by the target, enabling a great precision in aiming. The beam of the laser target designator is set to a pulse rate that matches that set on the guided munition to ensure munitions strike their designated targets and do not follow other laser beams which may be in use in the area. The laser designator can be shone onto the target by an aircraft or nearby infantry. Lasers used for this purpose are usually infrared lasers, so the enemy cannot easily detect the guiding laser light.

LASER SIGHT

5. The laser has in most firearms applications been used as a tool to enhance the targeting of other weapon systems. For example, a *laser sight* is a small, usually visible-light laser placed on a handgun or a rifle and aligned to emit a beam parallel to the barrel. Since a laser beam has low divergence, the laser light appears as a small spot even at long distances; the user places the spot on the desired target and the barrel of the gun is aligned (but not necessarily allowing for bullet drop, windage, distance between the direction of the beam and the axis of the barrel and the target mobility while the bullet travels).

HOLOGRAPHIC WEAPON SIGHT

6. A Holographic weapon sight uses a laser diode to illuminate a hologram of a reticle built into a flat glass optical window of the sight. The user looks through the optical window and sees a cross hair reticle image superimposed at a distance on the field of view.

MILITARISATION OF SPACE

COMPILED BY
S LT AMANPREET KAUR

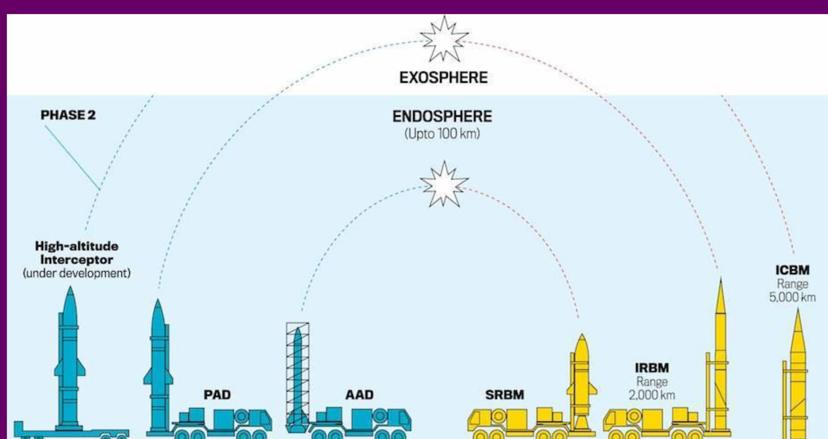
OUTER SPACE

1. The area outside of Earth's atmosphere and between celestial bodies is known as outer space. Space has been successfully explored by science and astronomy in recent years and its use for a wide range of civic and military objectives has grown significantly. Approximately 1,000 satellites are thought to be in use today and are owned by more than 60 nations.

SPACE WEAPONS

2. In general, space systems such as communications, PNT [position, navigation and timing] or intelligence gathering that serve only as passive support to other forces are also not regarded as space weapons. The space-based air defence system must, like any other air defence system, have sensors to find and track enemy missiles from the moment they are launched. The space-based air defence system must, like any other air defence system, include sensors to find and follow an enemy missile from the moment it is launched, have kill weapons to shoot it down, and any necessary command and control components. These could primarily be divided into four categories: direct attack weapons, such as nuclear explosions, directed energy weapons (DEWs), particle beam weapons (PBWs) and Kinetic Energy Weapons (KEWs), as well as reconnaissance and intelligence weapons.

3. Weaponisation and Militarisation of Space also discusses the creation of military space-based assets with auxiliary ground systems for early warning, communications, command and control, monitoring (remote sensing), National Technical Means (NTM) and Position Navigation and Timing (PNT) that can be used for verification, surveillance, and intelligence. It enhances weapon targeting, strategic and battlefield monitoring, command and control, and communications to establish their dominance over other military space users. Today, weaponry may be permanently deployed outside of the Earth's atmosphere and subsequently bombard target bases and cities in response to a signal from the planet. This is in addition to the existence of missiles that can travel into space.



4. Intercontinental Ballistic Missile (ICBMs) development was the first military use of space. With this, the need for defence against this kind of weapon became apparent. It doesn't appear possible to stop a nuclear-armed missile as it approaches its target at 20 times the speed of sound during the "terminal phase" since, should the missile be struck, the resulting explosion would destroy the area being protected. Destroying the missile mid-course, after it has left the atmosphere, while it travels through space and before it re-enters the atmosphere close to its target is thus the most appealing alternative. The innate trust and cooperation required to maintain the systems deployed in space for peaceful reasons would be destroyed by a space conflict. The desire to establish military dominance in space stems from two primary concerns the first is a lack of confidence in the capability of the current missile defence system to stop an incoming ICBM carrying a nuclear warhead and the second is the need to protect one's own satellites from other anti-satellite (ASAT) weapons.

5. **Weaponisation and Militarisation of Space**. When space is militarised, it aids armies on the traditional battlefield, but when space is weaponized, it becomes the actual battlefield.

(a) **Militarisation of Outer Space**. It refers to the use of space in support of ground, sea and air-based military operations.

(b) **Weaponisation of Space**. The term "spatial weaponisation" describes the deployment of destructive space-based technologies into orbit. Despite not officially being a component of the weaponization of space, ground-based devices that are utilized or planned for space-based attacks nevertheless count as space weapons. The use of a wide spectrum of space weapons, such as satellite-based Ballistic Missile Defense (BMD) systems, space-based Anti-Satellite (ASAT) weapons and various Space to Earth Weapons (STEWs), would constitute space weaponization.

SATELLITES AS VEHICLES OF SPACE WEAPONS

6. Low Earth Orbit (LEO) satellites orbit the planet every one to three hours between300 and 1,000 km above the surface. LEO travels at extremely high speeds, between 7 and 8 km/s, or 30 times faster than a 747 jet. The earth is imaged in high resolution by satellites in LEO orbits.

7. The Global Positioning System (GPS) and navigation systems use Medium Earth Orbit (MEO) satellites, which orbit the earth less frequently. Geosynchronous Orbit (GEO) satellites orbit the earth at a height of 36,000 km, taking 24 hours to complete one orbit. The majority of these are meteorological and communication satellites. Once a satellite's orbit is known, it can be precisely tracked and is therefore open to attack. A satellite in LEO can be destroyed by a medium-range ballistic missile (MRBM). Countries like the US have shown how dependent they are on satellites for military command and control, communication, target identification, weapon guidance and fire direction. They will be protected by highly developed weapons, most of which will be based in space.

8. There are multiple advancements in the field, following are the latest projects:

(a) **Space-Based Lasers (SBLs)**. These would operate in low-earth orbit and shoot down enemy ballistic missiles during their boost phase. These are divided further into two categories. A point defence system to stop mortars, rockets, artillery and cruise missiles is being developed by the US and Israel under the name Mid-Infrared Energy Chemical Lasers (MIRACL). Chemical lasers are giving way to solid state lasers in terms of technology because of the latter's superior potential. They don't use ammunition, in contrast to chemical lasers, which need chemicals, SSLs only need electricity.

(b) **Space-Based Missile Interceptors**. The satellites in this system would hit their targets with the incredible speed only achievable in LEO to destroy them through kinetic contact.

(c) **Electro-Magnetic (EM) Rail Guns**. This is likely to be the centra component of any STEW. They have the greatest potential for deployment in space and are expected to eventually replace all conventional guns.

(d) **Evolutionary Air and Space Global Laser Engagement (EAGLE)**. Mirrors will be placed beneath a sizable airship as part of the initiative. The hostile missile would be tracked or destroyed using lasers fired from the ground, air or space and reflected off this blimp borne mirrors.

(e) **Space-Based Infra-Red (SBIR)**. Ballistic missile defence interceptors will be guided by the space-based infrared (SBIR) system in three phases, namely boost, mid-course and terminal. Additionally, it would significantly increase information, surveillance and reconnaissance capabilities while also providing warning of missile launches. Both LEO and GEO would observe its deployment.

(f) **Space Tracking and Surveillance System (STSS)**. A constellation of low-earth orbit (LEO) sensor satellites called the Space Tracking and Surveillance System (STSS) will track enemy missiles, distinguish between warheads and decoys and evaluate the results of potential interceptions.

(g) **Anti-Satellite (ASAT) Weapons**. Various supporting technologies are currently being developed in order to create anti-satellite weapons. High power lasers, miniature satellites, Kinetic-Energy Anti-Satellite (KE-ASAT) weapons, Near Field IR Experiment (NFIRE), etc. are some of these.

(h) **High Altitude Nuclear Detonation**. All nuclear-armed states can carry out high altitude nuclear explosions, which are an efficient way to destroy satellites. These are a powerful means of eliminating satellites.

(j) **Global Strike Programme**. With a 30-minute response time, this project aims to drop sensors or bombs anywhere on the surface of the earth from orbit. The Common Aero Vehicle (CAV) project aims to create an autonomous, maneuverable spacecraft outfitted with sophisticated sensors and weaponry. For high payout targets, this would be capable of reaching a global area.

(k) **Rods from Gods**. Also known as the brilliant space weapon, launch 20-foot-long orbital tungsten or uranium rods that would strike terrestrial targets at a speed of more than 10,000 kilometers per hour by entering the earth's atmosphere utilising the accelerating force of gravity.

9. If space weaponization become a reality, orbital slots, radio frequencies and the problem of space debris are just a few of the alarming problems that would become much more complicated. Particles as small as one-tenth of a millimeter in diameter can destroy satellites and spacecraft. The United Nations first proposed an Outer Space Treaty in 1967. The treaty places a strong focus on the idea that space exploration should benefit all of humanity and all countries and it should be done peacefully. Such agreement would: -

(a) Ban production, developing, testing, deploying, and using weapons in space.

(b) Prohibit the development, production, deployment, and/or use of earth-based space-operating weapons.

(c) Impose notification requirements for all upcoming space activities.

(d) Create oversight and validation.

(e) Create methods for monitoring and verification

(f) Include processes for resolving disputes over military use of space and enforcement methods for treaty violations.

UNMANNED UNDERWATER VEHICLE AND OTHER UNDERWATER DEVELOPMENTS

COMPILED BY
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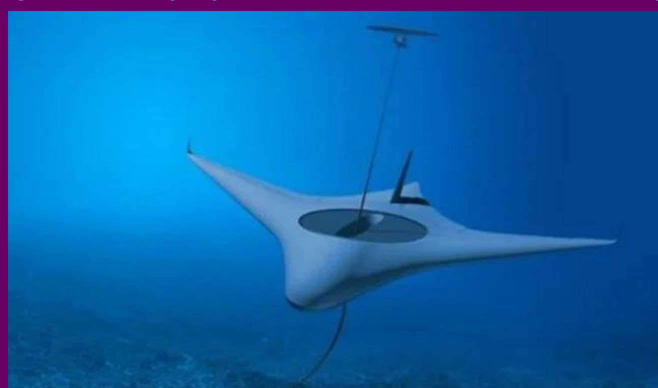
INTRODUCTION

1. Robots and AI is something that has taken over the world of military weapons. Battlefield is slowly going unmanned. Underwater is no such exception and research related to it has skyrocketed in recent years. A successful outcome of this is unmanned underwater vehicle or unmanned submarine vehicles.

UNMANNED VEHICLES CHANGING THE SCENARIO

2. Ocean environment has been one of the most challenging environments when it comes to weapon deployment and data collection. This is due to low accessibility. In such an environment when a submarine goes for deployment, it is considered extremely dangerous. Its chances of getting caught if any weapon is launched it extremely high and If caught it will directly lead to loss of life and money in terms of expensive submarines. Unmanned vehicles can come as a great help in such situations. As the name suggests, these can operate underwater without human occupant being remotely controlled from land or some platform on sea.



3. The **Categories of Unmanned Vehicle** can be divided into the following: -

(a) **<u>Remotely Operated Underwater Vehicles</u>**. A remotely operated vehicle, even though unoccupied, is connected to a ship via cables. Like how cables transfer commands to torpedoes during launch, here also the cables are used to transfer commands to vehicle allowing remote navigation of vehicle. It contains various additional facilities like a camera, sonar, light etc. its main use is for vessel hull inspection.

(b) **<u>Autonomous Underwater Vehicle</u>**. Also called uncrewed vehicles it conducts its operations without human intervention while operating it. Unlike ROVs it is not connected via cables. As the mission is completed it can return to its initial location and data can be extracted and manipulated accordingly.

4. **Advantages**. They allow access to difficult to access environments and provides a dynamic environment when it comes to data collection. What separates it from already existing ASW technologies is its unmanned characteristics and relatively smaller size for mobility. It can use technologies like active sonar to detect and track adversary. During data collection it can also categorize data. Such vehicles can be launched by submarines underwater. It has cons when it comes to expenses also. Being small in sizes it can be made at a relatively low cost. At the cost of one submarine, hundreds of such vehicles can be produced.

5. **Current ASW Scenario**. Any ASW operation is generally a combined effort of fixed wing aircraft, submarines and ships. But they will be limited in endurance and restrictions because of size to keep track for a long time. But an unmanned vehicle with great endurance patrolling 24X7 will be a great benefit as compared to today's scenario.

6. **Current Uses**. It can be applied for various uses but in current scenario its restricted obtaining maps of deep seas, characterizing physical, chemical and other such properties of water, establishing pervasive presence in ocean etc.

EXAMPLES

7. Following are examples of famous underwater vehicles: -

(a) **Sentry**. It is a car sized underwater vehicle developed by Woods Hole Oceanographic. It is used to navigate complex terrains. It has a sophisticated communication and navigation system. It is capable of taking digital photographs in a variety of deep-sea terrains.

(b) **ORCA**. It is an extra-large underwater vehicle made by Lockheed Martin. It's work includes delivering payload, loitering in the area and establishing communication.

INTEGRATION OF RPA AND MOTION CAMERA IMAGERY IN MI 17 V5

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INTRODUCTION

1. Indian Defence procurements have taken to new roads since the last few years and what we see in the pipeline is a plethora of modern aircraft which take us to a new level of defence capability. Especially in the helicopter fleet, a lot remains to be done to make good our ageing fleet of the Mi class of helicopters which form the backbone of Indian Air Force's helicopter fleet. The introduction of Mi 17 V5 aircraft is a boon in terms of modern navigational capability but the same technology has been in vogue for decades now in other modern helicopters throughout the world. Keeping the procurement process delay, the constraints of limited numerical availability, indigenous productions and rapid worldwide development in technology, there exists a need to make good use of off the shelf avionics, navigational and other modern equipment for modernizing the capable Mi 17 V5 aircraft so that they can be utilized in the best possible manner in roles other than what have been envisaged in the Air Operations Planning Process. The capabilities brought in by our purchases over the last decade might be a leap forward from our existing capabilities but are nothing new to the outside world. Limited capability of these so-called state of the art systems render the MLH fleet in a flux where we might be able to expand the envelope of helicopter operations but to a very limited extent.

SPLITTER AMPLIFIER

2. Apart from the standard equipment, the MI 17 V5 aircraft are equipped with a less known and even lesser utilized Splitter Amplifier that is analogous to a Universal Serial Bus in a computer which can be utilized over a wide spectrum for various other equipment's. This Splitter Amplifier is a millimetric jack which is integrated with the Multi-Function Displays. The same can be utilized to provide pre-recorded or live-feed video or image data. This can be facilitated by the fitment of any digital camera with a compatible jack, a digital tough pad or similar equipment which can be utilized for various purposes. Feed from external Electro Optical Infra-Red Pods can also be fed from the same. The videos can be displayed on the FLIR page of MFDs and photos on the Photo page. A serial or HDMI port with the equipment can utilized to display video output on the MFDs. A serial/HDMI to RCA converter cable is the only additional equipment that would be required to provide video output on the MFDs.

SCOPE OF INTEGRATION

3. The GOPRO cameras have revolutionised the digital camera industry by providing a video and still image capture capability. The camera can be affixed on mounts custom built or provisioned along with the camera itself and be integrated to provide real time imagery of the target upfront or looking out for any threat in the rear quarters. Trials have been carried out with the camera fixed to give a live feed of the target in the front with the pipper of the sight visible. This was utilised to carry out real time assessment of targeting. The video can further be downloaded for carrying out debrief and training of aircrew.

4. **UAV Video Imagery Receiver**. Exploitation of downlinked video provides airborne and ground forces with enhanced situational awareness and timely warnings of threats and enemy intentions, buying valuable time to react to the fast-moving or escalating tactical situation. This enables the user to receive, record or rebroadcast digital and analog video from unmanned aerial vehicles, strike pods or ground-generated sources. A range of optional appliqué modules can incorporate tailored platform downlinks. It is compact, designed for use alongside or integrated with the onboard integrated targeting system. The display removes the tactical threat of computer screen illumination at night while enabling hands-free video viewing on demand. For those who already use the analog-only version, the equipment retains the same accessories and power sources for a virtually seamless user transition to the system. In helicopter operations, the equipment offers a mount and antennas to allow rapid, mission-specific installation. This reduces the inventory required to support deployed operations. Aircraft-installed options include: a local recording and replay unit, enabling rewinding, replay and storage of received video; the TacTest video test transmitter, allowing generation and transmission of local video for system test prior to deployment or for remote transmission of other video sources and aircraft to aircraft video rebroadcast capability, allowing downlinked video transmission from the receiving aircraft to other members of the package.

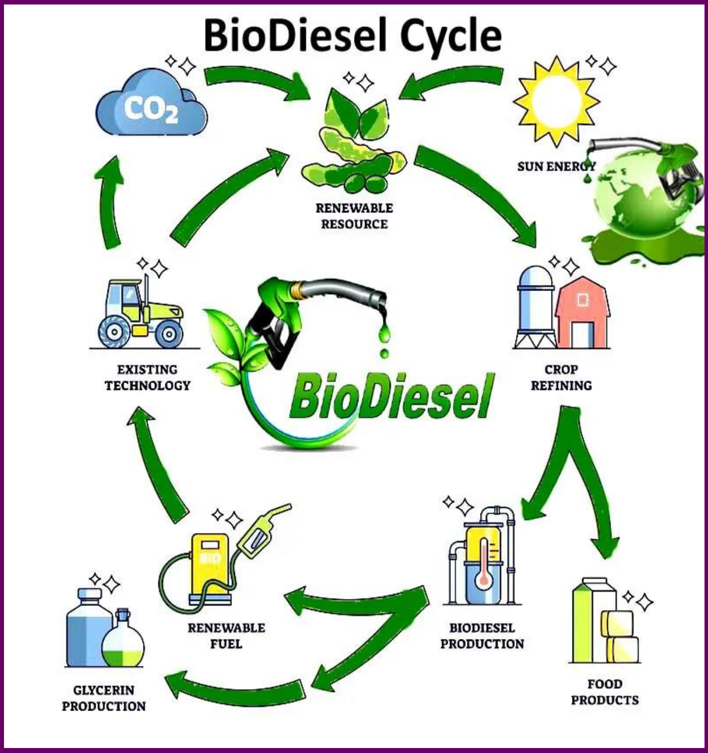
5. IAF is a technology intensive arm of our defence forces. The pace at which the world around us is changing, there exists a need to pace up at which we are embracing modern technology. Whilst the country is still developing and the defence budget is limited wherein only a fixed amount of money can be spared for defence procurements and the same extending to almost a decade before the procurement gets completed, it is prudent that we embrace any modification that can enhance the capability of our fighting machines. Integration of RPA imagery using splitter amplifier will enhance the situational awareness of the pilots and forewarn them about the presence of enemy forces, terrain lying ahead as well as the presence of adverse weather enroute which will help prevent a large proportion of accidents. Mi 17 V5 helicopters are one of the most versatile machines available in our defence forces which have the scope of seamless modification. With the methods mentioned earlier, not only can we enhance the potential of this machine but can also open new avenues for its employability.

UTILISATION OF BLENDED BIO-DIESEL FOR INDIAN AIR FORCE

COMPILED BY
SQN LDR BS RAJA SEKAHR, DSTSC(AF)-05

1. CSIR-IIP (Council of Scientific and Industrial Research, Indian Institute of Petroleum) Dehradun's home-grown technology to produce bio-jet fuel has been formally approved for use on military aircraft of the Indian Air Force (IAF). The provisional clearance (PC) certificate was handed over by Director (AT&FOL), Centre for Military Airworthiness and Certification (CEMILAC) to Scientists from CSIR-IIP in the presence of Reps of the IAF and CEMILAC. This certification represents India's growing confidence in aviation biofuel sector and another step towards 'Atmanirbhar Bharat'.

2. The technology, developed by the Indian Institute of Petroleum (CSIR-IIP), a constituent laboratory of the Council of Scientific and Industrial Research, has undergone evaluation tests and trials over the last three years. The testing of airborne fuel items is a complex and meticulous process involving intricate checks while ensuring the highest levels of flight safety. International aviation standards define the scope of these rigorous assessments. Fuel being the lifeline of aircraft requires thorough analysis before being filled into manned flying machines. The certification received by the lab today is an acknowledgment of the satisfactory results obtained from various ground and inflight tests performed on the indigenous bio-jet fuel by various test agencies supported by the IAF.



3. On 26 Jan 19, an AN-32 aircraft, filled with blended bio-jet fuel, had flown over Raj Path at New Delhi during the Republic Day celebrations. Thereafter, the performance and reliability of the Indian technology were also tested when the AN-32 safely landed and took off from Leh airport on 30 Jan 20 at high altitudes under severe winter conditions. The fuel was also used on a civil, commercial demonstration flight operated by SpiceJet on 27 Aug 18 from Dehradun to Delhi. These test flights with green fuel underscored the capabilities and commitment of Indian scientists and airmanship of IAF to serve a national cause.

4. The approval by CEMILAC (Centre for Military Airworthiness and Certification) is a culmination of many years of intensive research and active support of many agencies, including the test facilities of Indian Oil Corporation (IOCL) Panipat Refinery and Hindustan Aeronautics Ltd. (HAL). This clearance will enable Indian armed forces to use bio-jet fuel produced using indigenous technology across all its operational aircraft. This will also enable early commercialization of the technology and its mass production. Indian bio-jet fuel can be produced from used cooking oil, tree-borne oils, short gestation oilseed crops grown off-season by farmers and waste extracts from edible oil processing units. It will reduce air pollution by virtue of its ultralow sulphur content compared with conventional jet fuel and contribute to India’s Net-Zero greenhouse gas emissions targets. It will also enhance the livelihoods of farmers and tribals engaged in producing, collecting and extracting non-edible oils.

5. The global aviation industry, both civil and military, is one of the biggest emitters of greenhouse gases which cause global warming. It is imperative that the industry finds ways to reduce its carbon footprint for global efforts to achieve ‘net zero emissions’ to be successful. The annual fuel consumption of the IAF for 2021-22 was 6.2 lakh kilo litres, which contributed around 15 lakh tonnes of carbon dioxide.

6. On the civil aviation front, an official from aircraft manufacturer Airbus said it had plans to offer 100% sustainable aviation fuel (SAF) compatibility on its commercial aircraft latest by 2030. Global Aircraft Manager ‘Airbus’ mentioned their plan is to be the first major aircraft manufacturer to offer a climate neutral commercial aircraft by 2035, as told by Project leader, SAF of Airbus.

7. The biofuel produced in India was extracted from Jatropha plant seeds using a technology patented by the Council of Scientific and Industrial Research (CSIR) and the Indian Institute of Petroleum, Dehradun. The project for the development of blended fuel was conceptualised in January 2018 with CSIR and IIP Dehradun as the development agency. The development order was issued on October 17, 2018, for the delivery of 8,700 litres of blended fuel at a cost of ₹ 5.43 crore, as quoted by IAF.The plan is eventually to expand the usage of aviation turbine fuel blended with bio-diesel to all fixed-wing and rotary-wing aircraft through evaluation and certification. Such usage has the dual benefit of reducing carbon footprint as well reducing the usage of fossil fuels, which will also result in savings for the IAF. However, there are significant challenges in production and supply chain to ensure the IAF gets enough Jatropha and at reasonable rates. Availability of biodiesel in enough quantities is the biggest challenge, as the IAF would require over 3,000 KL of biofuel annually just for operating AN-32 fleet with a 10% bio fuel mix.

8. The country’s first mass production bio-ATF plant is being set up by Mangalore Refinery and Petrochemicals Limited (MRPL), a subsidiary of ONGC, fully integrated with its refinery at Mangaluru in Karnataka. The Ministry of Petroleum and Natural Gas had advised MRPL to set up a bio-ATF plant integrated with its refinery in September 2020. The MRPL board has approved the project to set up a demo-plant to manufacture 20 KLPD at an approximate cost of ₹300 crore in August 2022 and the plant is expected to be ready in 2025.

SUPERSONIC MISSILE ASSISTED RELEASE OF TORPEDO (SMART)

COMPILED BY
S LT LAKSHMI BHADANA, NTSC-41

INTRODUCTION

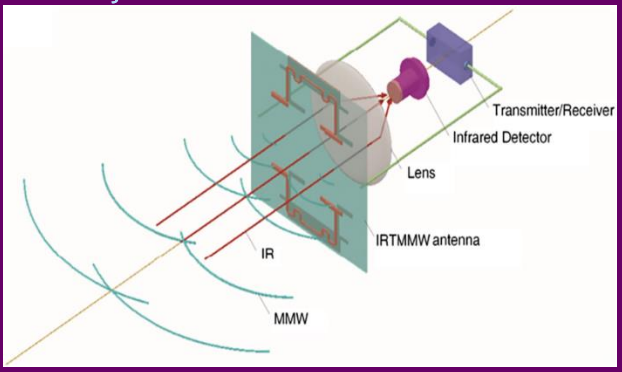
1. A modern torpedo is the most preferred lethal weapon system to destroy naval ships and submarines. A torpedo has a destructive power higher than a missile because their underwater explosion causes bubble formation against the hull of the ship or submarine resulting in breaking it. They can also easily differentiate between a target and a decoy. The only challenge with respect to torpedoes is their limited range and low speed. The launching platform will not be much far off from the target. To overcome this challenge, on 05 Oct 2020, DRDO successfully flight tested the Supersonic Missile Assisted Release of Torpedo (SMART) from Wheeler Island off the coast of Odisha. This system is a next-generation missile-based standoff torpedo delivery system. It has been designed to enhance anti-submarine warfare capability far beyond the conventional range of the torpedo. SMART system has been jointly developed by DRDO laboratories, viz., Defence Research and Development Laboratory (DRDL) and Research Centre Imarat (RCI), both in Hyderabad, Aerial Delivery Research and Development Establishment (ADRDE), Agra and Naval Science and Technological Laboratory (NSTL), Visakhapatnam.

2. Torpedoes are self-propelled weapons that travel underwater to hit the target and can be fired from either above or under the water surface. SMART is a canisterised missile system consisting of advanced technologies such as two-stage solid propulsion, electro-mechanical actuators and precision inertial navigation. In this system the torpedo is launched from an existing supersonic missile system which takes the torpedo to a much longer range.

3. The supersonic missile has a range of 50-650km whereas the lightweight torpedo has 30km range. As the missile will be launched from the platform, it will seek the target which is a submarine. As the target whereabouts are confirm, the torpedo will eject out from the missile and onto the target. The torpedo will further perform target detection, tracking and interception under water. It will like a conventional torpedo perform lost target search in case the target is lost. The main advantage of this system is that the torpedo can be fired from long distance.

TECHNOLOGICAL ADVANCEMENTS

4. **Millimeter Wave Seeker (MMW)**. Millimeter radio waves are EM waves with wavelength between 1 and 10 millimeters. They are also called the millimeter band. They have respective frequencies of 30-300 GHz, which constitutes the lower part of the "Terahertz gap" – a wider spectral range extending from 100 GHz to 10 THz. The millimeter wave technology is applied mainly in radio Detection and Ranging (RADAR) systems. This technology uses millimeter and centimeter waves to determine the range, location, or velocity of objects. It can be used to detect aircraft, cars, ships, missiles and to survey the terrain. In structural sense, basic radar system consists of a transmitter and a receiver (often with the same antenna used for transmitting and receiving) arranged in such a way as to measure the electromagnetic echo produced by a distant target. Then, various signal processing techniques are employed to retrieve the desired information about the target.



5. One of the most significant issues in millimeter wave technology is that absorption by the atmospheric gases throughout the band increases with frequency. Fortunately, there are only few specific absorption peaks in this region, mainly at 24, 60 and 184 GHz. At intermediate frequencies, millimeter waves have much less atmospheric attenuation and propagate over greater range.

6. **Electro-mechanical Actuators**. An aerospace application of actuators involves a device which can change its direction and follow a desired path. The object can dynamically change its trajectory and moves from point A to point B. The object can change its direction with the help of fins, or flaps. These flaps/fins generate a torque due to aerodynamic friction present in the atmosphere and this torque rotates the object flying in the atmosphere.

CONCLUSION

7. The SMART system is one of its kind giving a different edge to the deadliest underwater weapon which is a torpedo. Successful operation of this system will enhance the range of ASW weapon drastically. The project is under trial phase by DRDO and will take time to deploy onboard *IN* ships.

INTERNET OF BEHAVIOURS IN MILITARY TECHNOLOGY

COMPILED BY
S LT TWINKLE SHERON, NTSC-41

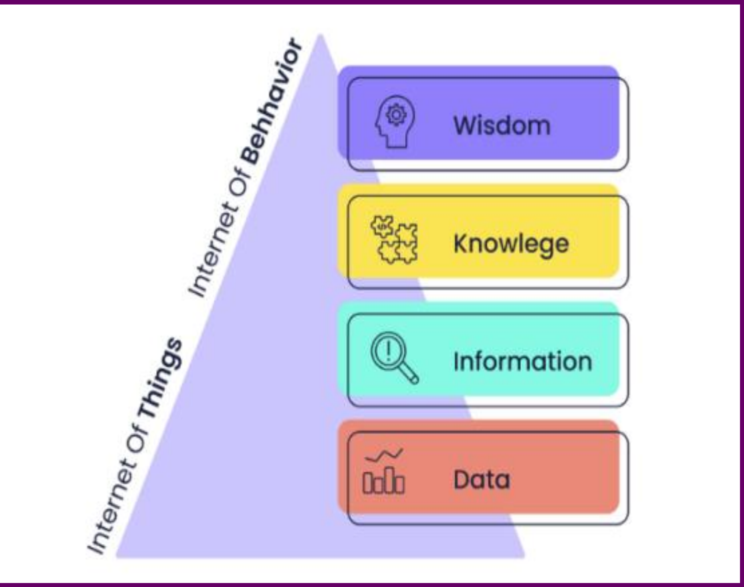
INTRODUCTION

1. Internet of things (IoT) is the network of physical devices that are interconnected and gather, share information and data through the internet. Internet of Things is changing in complexity and becoming complex each day. The way in which the devices are interconnected, the calculations are performed, and the data is being stored are turning into complex tasks. When we talk about internet of behaviours (IoB), it refers to collection and analysis of data that is of behaviour, interest, and preferences. It has more to do of the human aspect of it. Startups are now using Internet of Behaviour in deciding drinks for the customers based on their sex, age and mood but there is a wide scope of utilization of this technology in other fields. Its use in military is currently very limited, however their lies immense potential of IoB's exploitation.

INTERNET OF THINGS AND INTERNET OF BEHAVIOURS

2. The term "IoB" is a method of analyzing the user-controlled data from a behavioural psychology point of view. Internet of behaviour can be looked upon as an extension of IoT. The number of devices of IoT/IoB are increasing day by day as more devices are being connected to the internet. At the end of 2021, the total number of active IoT/IoB devices are around 12.2 billion, more than the total human population.

3. They are being utilized in all spheres of life, from medical to the military. In the domain of the military, it is deployed for combat purposes, including Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance. Situation awareness is one of the central aspects of Network Centric Warfare of Military. For this, real time data is collected, shared and reprocessed at the same time to gather information and formulate strategy.



USES IN MILITARY

4. One of the major uses is by adding devices to the combat soldiers. By sensing and computing devices worn by soldiers and embedded in their combat suits, helmets, weapons systems and other equipment we can acquire a variety of static and dynamic biometrics such as their face, iris, periocular space, fingerprints, heart rate, gait, gestures and facial expressions. In asymmetric warfare, it isn't always easy to identify enemy combatants. They can appear as civilians or access restricted military bases with a stolen badge. Sensors can scan irises, fingerprints and other biometric data to identify individuals who might pose a danger. Edge computing allows, for example, fingerprints from a weapon or bomb to be uploaded to the network and used to identify a combatant instantly. It can also confirm the identity of a target so a sniper can take him out.

5. Biometrics aren't just limited to identifying combatants. Sensors embedded in military uniforms and helmets can send information to a command center about a soldier's physical condition, helping him or her survive otherwise lethal enemy attacks. For example, pilots under g-force conditions or soldiers exposed to toxic chemicals can receive assistance. Edge computing can help soldiers gain access to vehicles and weapons systems as well as monitor battlefield conditions through, for example, connected drones.

6. Intelligence agencies track online activities of people they suspect to be a spy. Using Internet of behaviours, web activity of these people can be mapped and psychological analysis might help in detecting potential threats to the nation. One major drawback of utilizing these technologies in military is threat to security and leakage of information in cases of cyber-attack. In this dog-eat-dog world the most vulnerable things today are devices and specially breach of privacy over internet. Usage of internet of things and Internet of Behaviour combined with self-secure networks can change course of the wars or give an upper hand in general

ALTERNATIVE TO STEALTH TECHNOLOGY

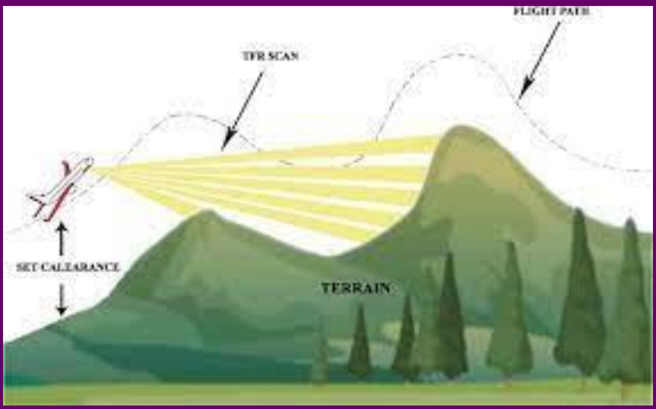
COMPILED BY

WG CDR JK SHARMA, DSTSC(AF)-05

INTRODUCTION

1. Terrain-flying radar (TFR) is a military aerospace technology that allows a very-low-flying aircraft to automatically maintain a relatively constant altitude above ground level and therefore make detection by enemy radar more difficult. It is sometimes referred to as ground hugging or terrain hugging flight. The term nap-of-the-earth flight may also apply but is more commonly used in relation to low-flying military helicopters, which typically do not use terrain-following radar.

2. TFR systems work by scanning a radar beam vertically in front of the aircraft and comparing the range and angle of the radar reflections to a pre-computed ideal manoeuvring curve. By comparing the distance between the terrain and the ideal curve, the system calculates a manoeuvre that will make the aircraft clear the terrain by a pre-selected distance, often on the order of 100 metres (330 ft). Using TFR allows an aircraft to automatically follow terrain at very low levels and high speeds.



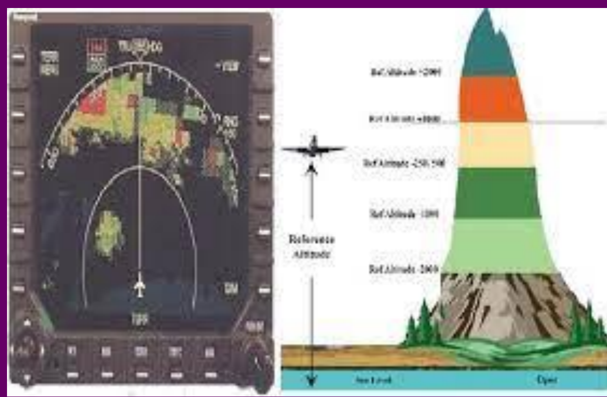
3. Terrain-flying radars differ from the similar-sounding terrain avoidance radars; terrain avoidance systems scan horizontally to produce a map-like display that the navigator then uses to plot a route that avoids higher terrain features. The two techniques are often combined in a single radar system, the navigator uses the terrain avoidance mode to choose an ideal route through lower-altitude terrain features like valleys and then switches to TFR mode which then flies over that route at a minimum altitude.

TECHNOLOGY

4. The system works by transmitting a pencil beam radar signal towards the ground area in front of the aircraft while the radar scans up and down. The reflections off the ground produce very powerful returns. The time the signal takes to travel to and from the terrain produces a range measurement to the terrain in front of the aircraft. The angle relative to the aircraft is returned by a sensor on the vertical gimbal that returns a calibrated voltage.

5. At the same time that the radar is sending out pulses, a function generator is producing a varying voltage representing a preferred manoeuvring curve. This is similar

in shape to a ski jump ramp, flat under the aircraft and then curving upward in front of it. The curve represents the path the aircraft would take if it was manoeuvring at a constant g-force, while the flat area under the aircraft extends forward a short distance to represent the distance the aircraft moves in a straight line before starting that manoeuvre due to control lag. The resulting compound curve is displaced by a pilot-selected desired clearance distance.



6. The system makes two measurements at the instant the return is seen. The first is from the vertical encoder on the radar measuring the actual angle to the terrain, and the second is from the function generator indicating the desired angle at the measured range. The difference between these two voltages is a representation of the angle between the radar's image and the preferred location. If the resulting voltage is positive, that means the terrain lies above the curve, negative means it is below. This difference is known as the angle error.

7. To guide the aircraft, a series of these measurements are taken over the period of one complete vertical scan out to some maximum distance on the order of 10 kilometres (6.2 mi). The maximum positive or minimum negative value of the angle error during the scan is recorded. That voltage is a representation of the change in pitch angle the aircraft needs to fly at to keep itself at the desired clearance altitude above the terrain while manoeuvring at the selected load factor. This can be fed into an autopilot or displayed on the pilot's heads-up display. This process produces a continually computed path that rises and falls over the terrain with a constant manoeuvring load.

8. Because the radar only sees objects in the line-of-sight, it cannot see hills behind other hills. To prevent the aircraft from diving into a valley only to require a hard pull-up, the negative G limit was generally low, on the order of one-half G. The systems also had problems over water, where the radar beam tended to scatter forward and returned little signal to the aircraft except in high sea states. In such conditions, the system would fail back to a constant clearance using a radio altimeter.

APPLICATIONS

9. Terrain following radar is primarily used by military strike aircraft, to enable flight at very low altitudes (sometimes below 100 ft/30 mts) and high speeds. Since radar detection by enemy radars and interception by anti-aircraft systems require a line of sight to the target, flying low to the ground and at high speed reduces the time that an aircraft is vulnerable to detection to a minimum by hiding the aircraft behind terrain as far as possible.

10. However, radar emissions can be detected by enemy anti-aircraft systems with relative ease once there is no covering terrain, allowing the aircraft to be targeted. The use of terrain-following radar is therefore a compromise between the increased survivability due to terrain masking and the ease with which the aircraft can be targeted if it is seen.

11. Even an automated system has limitations and all aircraft with terrain-following radars have limits on how low and fast they can fly. Factors such as system response-time, aircraft g-limits and the weather can all limit an aircraft. Since the radar cannot tell what is beyond any immediate terrain, the flight path may also suffer from "ballooning" over sharp terrain ridges, where the altitude becomes unnecessarily high. Furthermore, obstacles such as radio antennas and electricity pylons may be detected late by the radar and present collision hazards.

CURRENT EMPLOYMENT

12. On aircraft with more than one crew, the radar is normally used by the navigator and this allows the pilot to focus on other aspects of the flight besides the extremely intensive task of low flying itself. Most aircraft allow the pilot to also select the ride "hardness" with a cockpit switch, to choose between how closely the aircraft tries to keep itself close to the ground and the forces exerted on the pilot.

13. Some aircraft such as the Tornado IDS have two separate radars, with the smaller one used for terrain-following. However more modern aircraft such as the Rafale with phased array radars have a single antenna that can be used to look forward and at the ground, by electronically steering the beams.

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