"Altitude Our Attitude"

AERO –ANNUM

Department of Aeronautical Engineering

HINDUSTHAN COLLEGE OF ENGINEERING AND TECHNOLOGY, COIMBATORE.

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www. hicet..ac.in

About the Institution

Institute Vision

To become a premier institution by producing professionals with strong technical knowledge, innovative research skills and high ethical values.

Institute Mission

IM1: To provide academic excellence in technical education through novel teaching methods.
IM2: To empower students with creative skills and leadership qualities.
IM3:produce dedicated professionals with social responsibility.

Quality Policy

Hindusthan College of Engineering and Technology aims at providing the best education which will mould the students as the right characters, who will cater to the needs of the society. While providing the various inputs for the best education, Hindusthan College of Engineering and Technology will constantly thrive upon continual improvement with the utmost commitment for the complete satisfaction of the customer.

Hindusthan College of Engineering and Technology (HiCET) Coimbatore, established in the year 2000 by the great Industrialist and Philanthropist, Thiru.T.S.R.Khannaiyann of Hindusthan Educational Trust whose determination and dynamism made possible the realization of this institution of excellence. Surrounded with natures pristine beauty and an excellent infrastructure coupled with dedicated and experienced faculty has made the campus a much sought-after abode of learning. HiCET is one of the premier technological institutions inculcating quality and value based education through innovative teaching learning process for holistic development of the Students. The institution is recognized under Section 2(f) and 12B of University Grants Commission (UGC) and is an autonomous institution affiliated to Anna University , Chennai with permanent affiliation for most of the programmes, approved by the AICTE and the Government of India. Accredited by the National Assessment and Accreditation Council (NAAC) with ‘A’ grade, National Board of Accreditation (NBA).

HiCET conducts seminars and also invites companies to give presentations that will help our students to choose a right career for themselves and has hence contributed to the industry by successfully delivering fresh recruits who have contributed continuously to the growth of the industry by being a part of the top-notch organizations.For all these reasons HiCET has been a preferred institute for recruiting young minds.

Currently, there are around 5000+ students pursuing various Undergraduate programs (B.E./B.Tech.), Postgraduate programs (M.E./M.Tech, MBA & MCA) and Ph.D. research programs in the Institution and are mentored by above 400 well qualified and experienced faculty members. HiCET nurtures future global leaders by imparting knowledge, skills and building attitudes among students

About the Department

The Department of Aeronautical Engineering was established in the year 2005 and now headed by Mr.V.T.Gopinathan. The Department also inaugurated the Aeronautical Students' Engineering Association (ASEA) in March 2008. The Department is directed by a dedicated team of teaching and non-teaching staff with a wide range of experience, and it has well-equipped laboratories and good infrastructure to support the autonomous curricular needs. Until now, the department has been in the forefront of advancing aeronautical education and indigenous research in the field of aeronautics. The department has received numerous funds under different schemes for various projects. On the year 2018 the UAV lab and UAV club was established to invent and support the UAV sector.

Department Vision

To be a global player and prepare the students with knowledge, skills, and ethics for their successful deployment in Aeronautical engineering.

"Altitude Our Attitude"

Department Mission

M1:To nurture the students technically based on current trends and opportunities in the global Aerospace industry.

M2:To develop the students as innovative engineers to address the contemporary issues in the aeronautical field.

M3:To inculcate professional and social responsibility based on an innate ethical value system.

Program Educational Objectives (PEOs)

PEO 1: Graduates shall exhibit their sound theoretical, and practical knowledge with skills for successful employment, advanced education, research, and entrepreneurial endeavors.

PEO 2: Graduates shall establish deep-rooted mastering abilities, professional ethics, and communication alongside business capabilities and initiatives through lifelong learning experiences.

PEO 3: Graduates shall become leaders and innovators by devising engineering solutions for social issues in care of modern society.

Program Specific Outcomes (PSOs)

The graduates will be able to:

PSO 1:Apply the knowledge of aerodynamics, structures, propulsion, avionics, and aircraft maintenance to give solutions for complex engineering problems.

PSO 2:Use progressive methodology and tools involving design, analyze, and experiment in aircraft design.

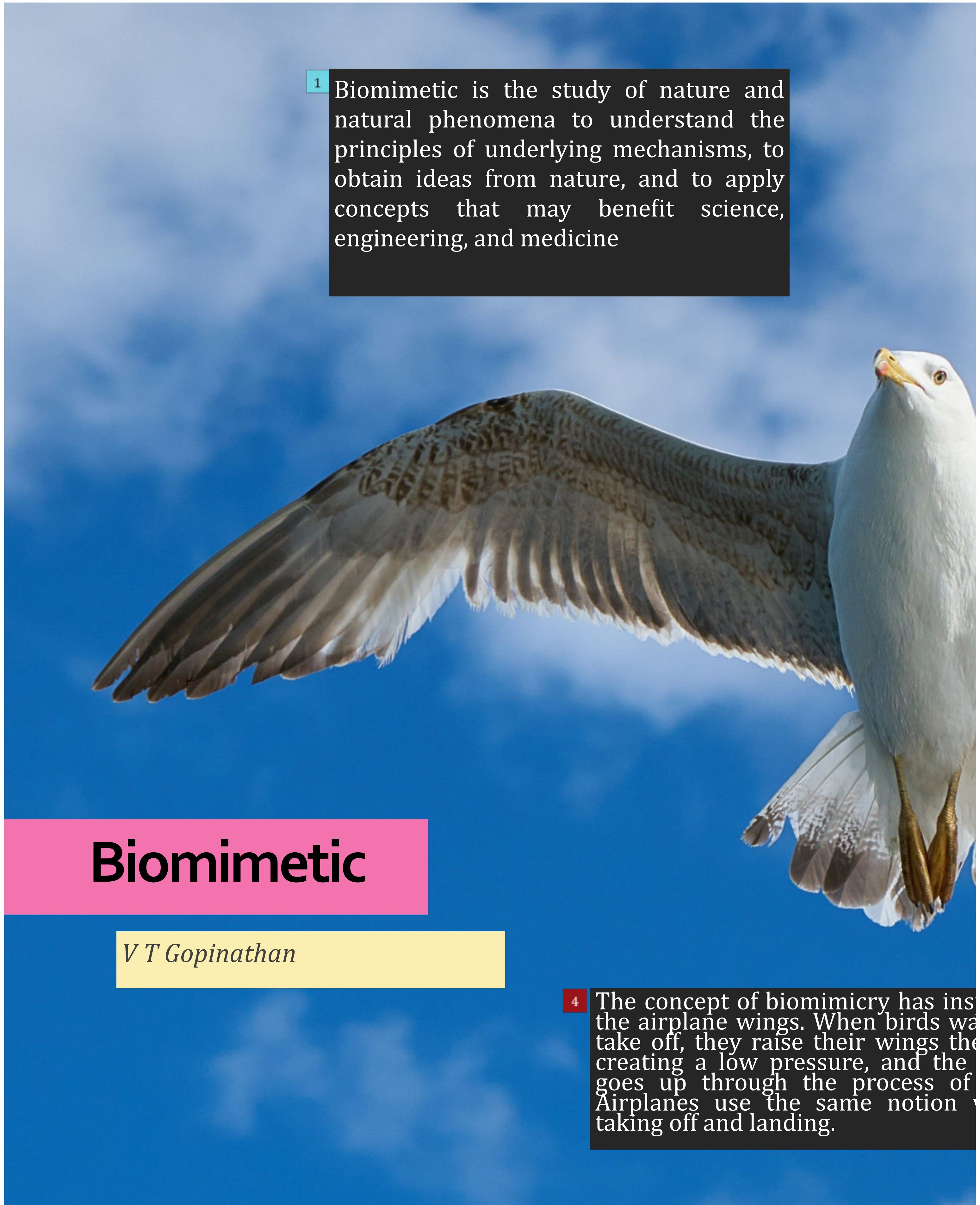
HOD's Message

"Learning is a treasure that will follow its owner everywhere"

A path for making innovations in the field of Aeronautics is laid by the Department of Aeronautical engineering of Hindusthan college of Engineering and Technology. The department has put the sincere efforts in going further in its attempts to excel the set standards and it has been involved in various effective activities supporting our country to meet all expectations in the field of Aerospace. The curriculum of the program is designed to meet the requirements of Aerospace organizations and their associates engaged in either production or R&D. The prescribed core courses cover important and exciting areas of Aeronautical Engineering including Aerodynamics, Aircraft Structures, Flight Dynamics, Propulsion, Avionics, Aircraft Design, Rockets, Missiles, Aircraft Systems, Instrumentations and Aircraft Maintenance. Aeronautical Engineering program also offers the courses in regard to the recent trends in Aerospace technology such as Unmanned Aerial Vehicle systems, Satellite technology, Cryogenics and Nano science. HICET UAV (Unmanned Aerial Vehicles) Club is a new addition which is monitoring by Aeronautical Engineering Department. It aims to train the students in design, assembly, simulation and flying of different UAV models, which make every student specialize in the area of Unmanned Aerial Systems, which will provide them additional carrier opportunities.

Mr. V T Gopinathan

HOD



Biomimetic

V T Gopinathan

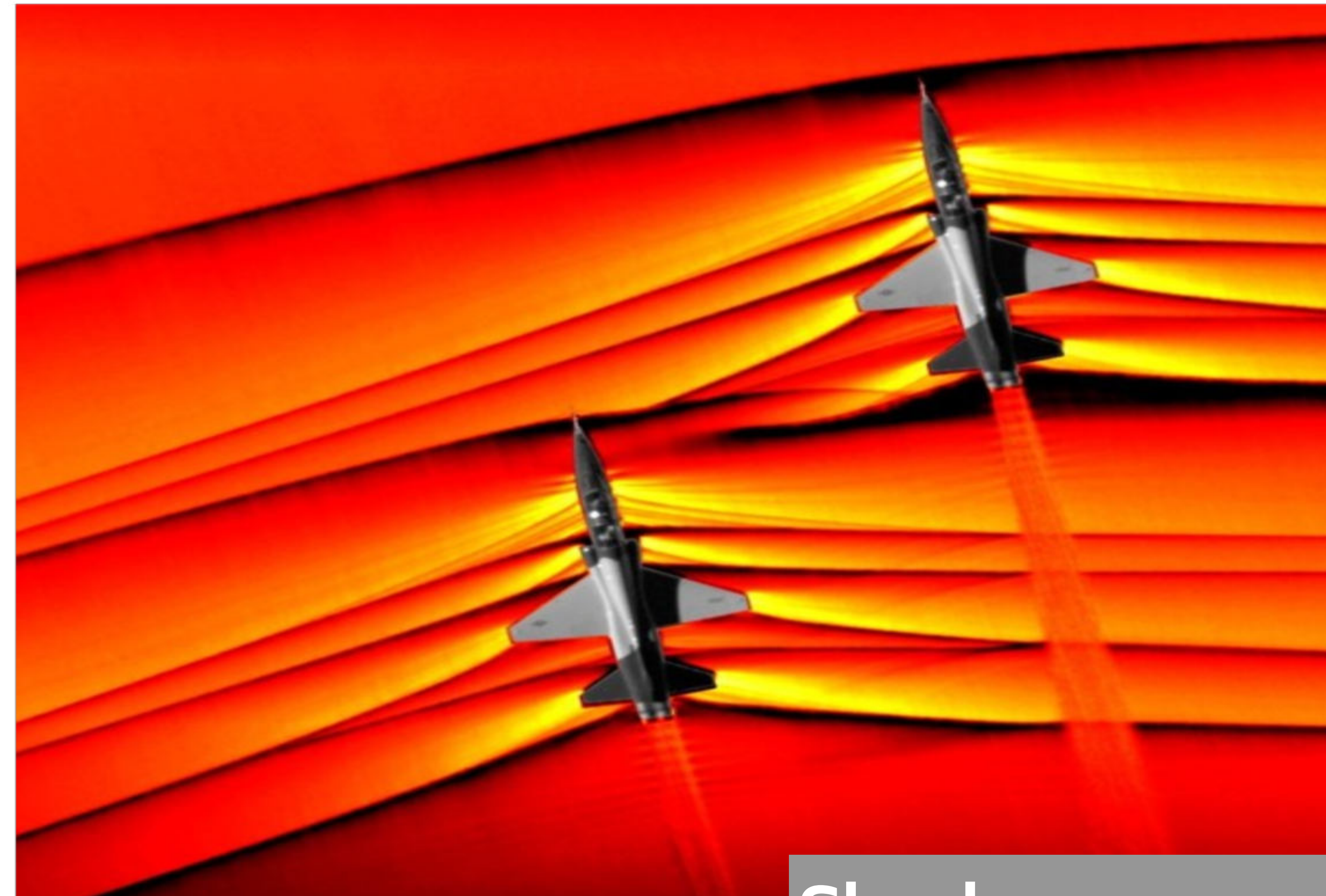
Biomimetic is the study of nature and natural phenomena to understand the principles of underlying mechanisms, to obtain ideas from nature, and to apply concepts that may benefit science, engineering, and medicine

The concept of biomimicry has ins
the airplane wings. When birds wa
take off, they raise their wings the
creating a low pressure, and the
goes up through the process of
Airplanes use the same notion
taking off and landing.

Biomimetics or biomimicry have been used and advanced even without formal research in many areas. Accumulating creative ideas as a foundation, mankind has accelerated the speed of development and evolution of civilization. However, such rapid industrialization has resulted in environmental pollution and a shortage of natural resources that is threatening the survival and future of humanity. As a result, it has become critical and urgent to find alternative methods to engineer materials, products, and services. Biomimetics is potentially the best method to help us cope with future development of civilization, environmental pollution, and resource shortage threats.

Examples of biomimicry:

- Down feather insulation. *Heavy winter coats are stuffed with down or other feathers so that we can stay warm without flying south for the winter*
- Termite mound cooling
- Humpback whale wind turbines
- Beetle water collection
- Spider web glass



Shockaeronz 20

Arun Raja KK & Chinnaiyah

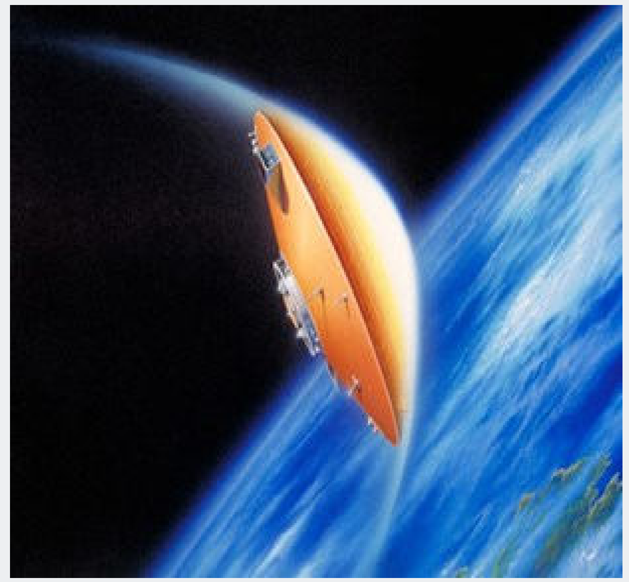
The 11th Technical Symposium was conducted in a grand manner with numerous participants from various institutions across the state.

Ballistic Re-entry of Space Vehicles

MUTHUMARI M (18101046)

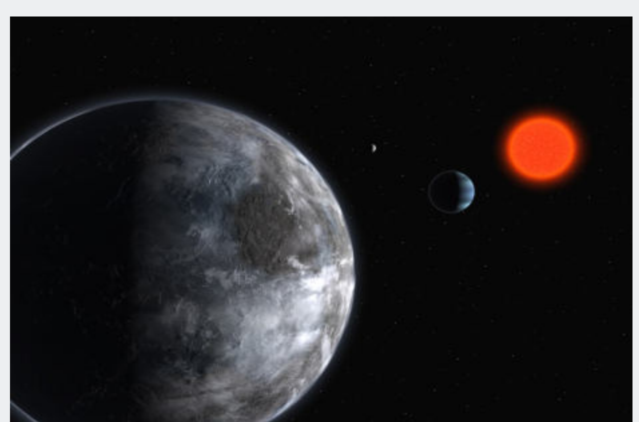
Hypersonic flight has revolutionized both commercials as well as military activity. The economic implications of affordable high-speed flight become apparent when one recognizes that hypersonic flight is an essential element at some point in the trajectory of all space vehicles during ascent and, if applicable, descent as well. Future hypersonic vehicles may also facilitate rapid transport between distant points on the earth at a fraction of the time it currently takes. Aerothermodynamics refers to the distribution of pressure, forces, moments, and heating on the vehicle. At high velocities and enthalpies, these are very large, and their minimization requires a compromise between conflicting considerations. The nose of the vehicle plays a very important role in the design of hypersonic vehicles.

For the blunt-body, the shock is curved and stands off (i.e., is detached) from the body – the region between the shock and the surface is termed a shock layer. The shock layer is thus a highly vortical region and is often termed an entropy layer. For the sharp-nosed configuration, the shock is weaker and is attached to the surface at its tip. It should be noted that even for a sharp-nosed body, there is always some bluntness at the leading edge, but the radius of curvature can be minimal.



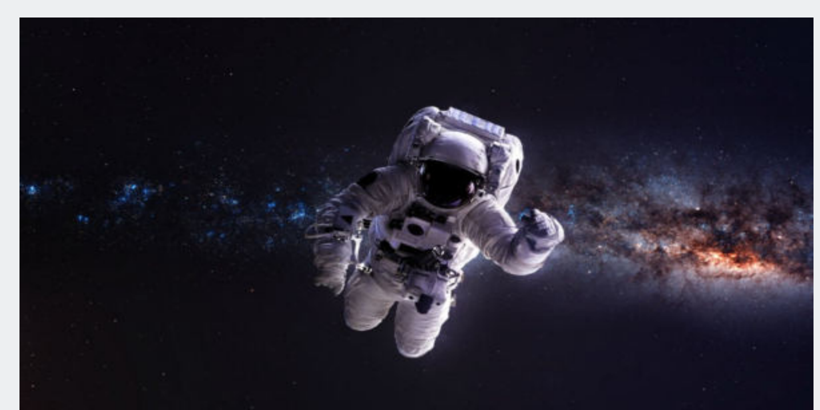
Re Entry space vehicle

For sharp-nosed objects, the angle between the shock and the surface becomes very small at hypersonic speeds. Drag is also an important consideration for vehicle design. Blunt noses, while reducing peak heating, increase the drag on the body.



A spacecraft approaching a planetary atmosphere from an interplanetary exploration mission possesses a large amount of kinetic energy. While the vehicle passes through planetary atmosphere this energy is converted into heat and at the same time the velocity of the vehicle is reduced greatly due to atmospheric drag, therefore the vehicle faces very high thermal and mechanical loads during re-entry. Trajectory analysis of such missions involves both dynamic and thermal requirements, and due to complex interacting phenomena, usually requires a numerical analysis. Analysis of reentry trajectories allows an attempt of systematic classification of spacecraft types and re-entry methods. As far as spacecraft is concerned, the aspect of lift to drag ratio leads to the difference between ballistic, semi -ballistic and lifting trajectories.

Blunt nose of the Re entry vehicle,



The cruise phase begins after the spacecraft separates from the rocket, soon after launch. The spacecraft departs Earth at a speed of about 24,600 mph (about 39,600 kph). The trip to Mars will take about seven months and about 300 million miles (480 million kilometers).

Man travels out of the atmosphere

Travel to mars is a possibilty

During that journey, engineers have several opportunities to adjust the spacecraft's flight path, to make sure its speed and direction are best for arrival at Jezero Crater on Mars. The first tweak to the spacecraft's flight path happens about 15 days after launch.

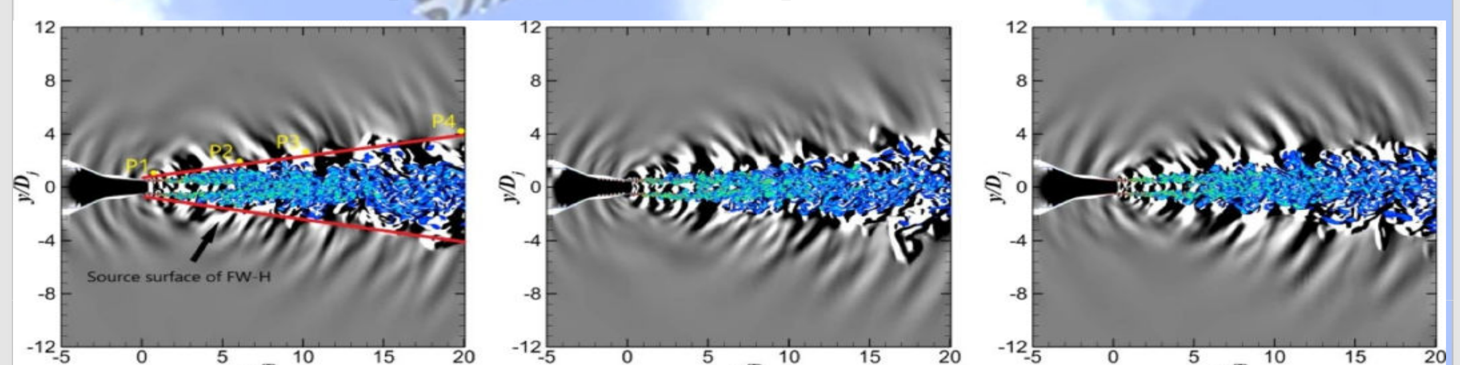
Noise control for high subsonic jet flows by inner wall treatment

Mithuna L (16101059)

Subsonic jet nozzles, commonly used in passenger aircrafts, generate significant noise that travels both downstream and upstream due to large-scale or fine-scale turbulence in the jet plume. To reduce jet noise, a novel wall treatment method, termed the wavy inner wall (WIW), is proposed. With this method, the smooth inner wall near the exit of the nozzle is replaced by treated walls that carry small wavy patterns. Numerical simulations were conducted to investigate the effects of the WIW treatment. Large eddy simulations (LES) were used to predict the unsteady flow field and the far-field noise, followed by the analogy method proposed by Fowcs Williams and Hawkings. To better understand the mechanism behind the noise reduction achieved by the WIW treatment, the shear-layer instability, radial and azimuthal auto-correlation functions, turbulent kinetic energy, and acoustic source term from the Tam-Auriault (TA) jet-noise model were analyzed. Results indicated that the WIW treatment advances the onset of jet flow instability in the shear-layer, leading to the early breakdown of jet shear-layer and production of different scales of downstream turbulent structures. As a result, the distribution and production of turbulent kinetic energy are affected, and the generation and emission of jet noise are controlled. The WIW treatment enables the control of fine scale turbulence, resulting in the reduction of mid- to high-frequency noise in the far field, while ensuring a low thrust loss. This feature makes the WIW method a promising approach for jet noise control.

In recent years, increasingly stringent environmental regulations have placed significant pressure on the suppression of aviation noise. Though researchers have made great strides in reducing jet noise from airliners, significant noise is still observed during takeoff , making jet noise control a more challenging task than ever.

The wavy wall is a widely used flow control technique to reduce flow drag, and several studies have been conducted on its drag reduction capabilities. However, there has been limited research on the performance and mechanisms of wavy wall in suppressing jet noise. Magnet conducted large eddy simulations of low-speed turbulent flow and found that the span wise wavy wall can generate additional noise. Passing through the wavy wall generates a more stable free shear shedding by the wall surface than the smooth one, which results in a suppressing effect on low-frequency sound sources. Chen et al. investigated the mechanisms of drag and noise reduction of the wavy cylinder and found that the pressure fluctuation on the wavy cylinder surface is suppressed, resulting in a significant reduction of the lift coefficient fluctuation. The overall sound pressure level (OASPL) of far-field noise radiated by the wavy cylinder is reduced, and the tones are significantly suppressed or eliminated. Chen et al. applied the wavy wall to treat the cove inner-wall of the 30P30N airfoil, and their results showed that low-frequency narrowband tonal noise was significantly suppressed while maintaining the aerodynamic performance. The wavy wall control method induces very small geometrical modifications, which introduces a trivial sacrifice in thrust while enhancing shear layer mixing. As a result, the wavy wall is a promising method for flow and noise control for subsonic jets. The noise control mechanism of the WIW-treated nozzles is attributed to the enhancement of jet mixing. The WIW treatment introduces several extra initial instability modes, which are superposed with the inherent instability modes of the baseline nozzle to accelerate the breaking-down of vortex rings near the jet exit. This results in jet flows that are much closer to isotropic turbulence, and compared to the baseline, the peak value of the TKE in the jet shear-layer is decreased by up to 16.3%. As a result, the location, strength, and scale of the jet noise source are modified. Visualizing the generation and evolution of jet noise using the pressure time gradient shows that this noise control technique is particularly efficient in the direction of 70° – 90°. By examining the noise source from the Tam-Auriault fine-scale turbulence noise model, it is found that the WIW treatment is effective in controlling all three key factors: the scaled TKE, the characteristic length, and the characteristic dissipation time of jet turbulence. This explains the ability of the WIW treatment to suppress mid- to high-frequency broadband noise.



CHANDRAYAAN-2

Chandrayaan-2 is an Indian mission to send an orbiter, lander, and rover to the Moon. The three vehicles launched as one combined spacecraft in July 2019 to lunar orbit, and the lander, carrying the rover, attempted but failed to touch down in the Moon's southern hemisphere. The orbiter continues to study the Moon from above.

The mission builds on ISRO's Chandrayaan-1 orbiter, which launched in October 2008 and operated for 10 months. Chandrayaan-2 features improved instruments and new technologies intended for future planetary missions. The orbiter is planned to operate for seven years, while the lander and rover were expected to survive one lunar daytime period had they successfully landed

Chandrayaan-2 mission objectives

The Chandrayaan-2 orbiter hopes to build on the data collected during the Chandrayaan-1 mission using improved instruments. Science goals include mapping the Moon's topography, investigating surface mineralogy and elemental abundances, studying the lunar exosphere, and looking for signatures of hydroxyl and water ice.

The lander was named Vikram, after Vikram Sarabhai, the founder of India's space program. It would have landed near the Moon's south pole, at a latitude of about 70 degrees south.

The mission cost approximately Rs.603 crore ($87 million).

What instruments does the Chandrayaan-2 orbiter have?

Terrain Mapping Camera 2 (TMC 2):
Used to create a 3D map of the lunar surface, TMC 2 is a miniature version of the Terrain Mapping Camera used onboard the Chandrayaan 1 mission. Its primary objective is mapping the lunar surface in the panchromatic spectral band (0.5-0.8 microns) with a high spatial resolution of 5 meters, on 20-kilometer swaths from orbit.

Chandrayaan 2 Large Area Soft X-ray Spectrometer (CLASS):
CLASS measures the Moon's X-ray Fluorescence (XRF) spectra to examine the presence of rock-forming elements such as Magnesium, Aluminium, Silicon, Calcium, Titanium, Iron, and Sodium. The XRF technique will detect these elements by measuring the characteristic X-rays they emit when excited by the Sun's rays.

Solar X-ray Monitor (XSM):
Supports CLASS by observing the X-rays emitted by the Sun and its corona, and measuring the intensity of solar radiation in those rays. Measures the full solar X-ray spectrum every second in the 1-15 keV energy range.

Orbiter High Resolution Camera (OHRC):
Captures images of the landing site from two look angles to generating DEMs (Digital Elevation Models) that will be used to search for potential hazards. Post-landing, they will be used for further scientific survey. OHRC images cover an area of 12 x 3 kilometers, and have a resolution of 0.25 meters.

Synthetic Aperture Radar (SAR):
An L- and S-band radar system used to detect water ice inside permanently shadowed craters, and globally map the thickness and electrical conductivity of the lunar regolith. This will be the first L-band radar mapper to orbit the Moon.

Imaging Infrared Spectrometer (IIRS):
Characterizes and maps the abundance of hydroxyl (OH) and molecular water in the Moon's polar regions. Sensitive to light with wavelengths between 0.8 and 5 microns.

Chandrayaan-2 getting reaqdy for its mission

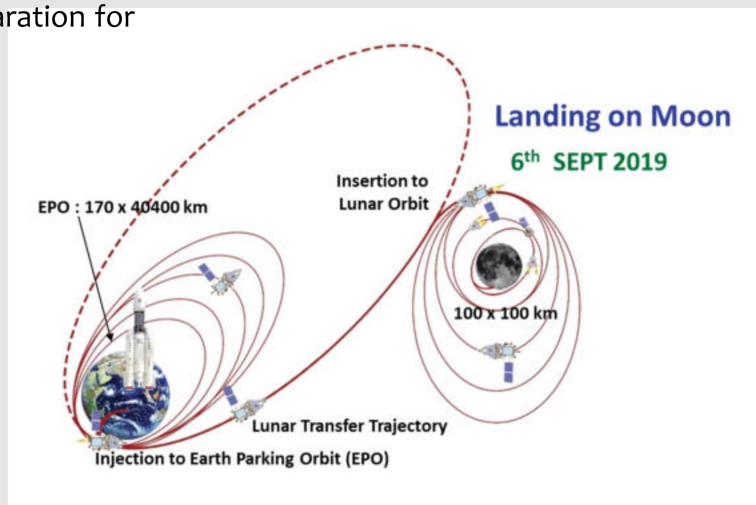
Chandra Atmospheric Composition Explorer 2 (ChACE-2):
A neutral mass spectrometer to sample atoms in the tenuous atmosphere above the Moon's polar regions. CHACE 2 builds on the CHACE experiment from Chandrayaan-2
Dual Frequency Radio Science (DFRS) experiment:
Studies the temporal evolution of electron density in the lunar ionosphere using X-band (8496 MHz) and S-band (2240 MHz) signals transmitted to Earth-based receivers.

Vikram lander and pragyan rover

On August 20, 2019, Chandrayaan-2 was successfully inserted into lunar orbit. While orbiting the moon in a **100 km lunar polar orbit**, on September 02, 2019, Vikram Lander was separated from the Orbiter in preparation for

Why did we go to the Moon?

The Moon is the closest cosmic body at which space discovery can be attempted and documented. It is also a promising test bed to demonstrate technologies required for deep-space missions. Chandrayaan-2 aims for enhancing our understanding of the Moon, stimulate the advancement of technology, promote global alliances and inspire a future generation of explorers and scientists.



DRONE SWARMS AND THE FUTURE

Arulmozhinathan T
AP-Aero

Imagine swarms of undersea, surface, and aerial drones hunting submarines hidden in the vastness of the ocean. Or imagine hundreds of airborne drones darting through New York City, seeking out targets and dosing them with nerve agent.

These imaginary scenarios are not yet reality, but they are quickly becoming so.

Drone swarm technology could have a significant impact on every area of military competition, from enhancing supply chains to delivering nuclear bombs. This article examines the implications for chemical, biological, radiological, and nuclear (CBRN) weapons. Some applications are already possible, while others are futuristic, but plausible. Our broader study in the Nonproliferation Review on the applications of drone swarms to CBRN weapons offers additional analysis.

Drone swarms offer significant improvements to both nuclear offense, the ability to successfully deliver a warhead to a target, and defense, the ability to prevent successful delivery and mitigate consequences. When it comes to chemical and biological weapons, drone swarms can improve both defense and offense, but appear to strongly favor offense by addressing key challenges to delivery. In the future, this could weaken the norms against these weapons and encourage proliferation. U.S. national security agencies should act to combat the threat and take advantage of the opportunities this new technology offers for CBRN weapons.

Military Advantages of Drone Swarms

Precisely defined, drone swarms are multiple unmanned platforms and/or weapons deployed to accomplish a shared objective, with the platforms and/or weapons autonomously altering their behavior based on communication with one another.

The fact that components of the swarm can communicate with one another makes the swarm different from just a group of individual drones. Communication allows the swarm to adjust behavior in response to real-time information. Drones equipped with cameras and other environmental sensors ("sensor drones") can identify potential targets, environmental hazards, or defenses and relay that information to the rest of the swarm. The swarm may then maneuver to avoid a hazard or defense, or a weapon-equipped drone (an "attack drone") may strike the target or defense. Real-time information collection makes drone swarms well-suited for searching over broad areas for mobile or other hard-to-find units.

But swarming also adds new vulnerabilities. Drone swarms are particularly vulnerable to electronic warfare attacks. Because drone swarms are dependent on drone-to-drone communication, disrupting that signal also disrupts the swarm. As swarms become more sophisticated, they will also be more vulnerable to cyberattack. Adversaries may attempt to hijack the swarm by, for example, feeding it false information, hacking, or generating manipulative environmental signals. Although numerous counter-drone systems are in development, current defenses do not appear sufficient and even promising systems will face scalability challenges, from deployment allocation to training, in the system's use.

Analysts are divided on whether drone swarms offer significant cost benefits. T.X. Hammes has posited in War on the Rocks that the future of warfare is "small, smart, and cheap platforms." He highlights swarms of drones as one example, arguing the costs are already low and likely to become lower. But Shmuel Shmuel disagrees, arguing in a skeptical essay that this new technology will be more expensive to

operationalize than most think.

Ultimately, the cost and its relevance depend in part on what role the swarm will play and what alternatives are available. Even multimillion-dollar drone swarms can be cost-effective on balance if they meaningfully increase the survivability of more expensive or particularly crucial platforms, such as aircraft carriers or nuclear deterrent forces. Simple, low-cost drones may also fill capability gaps, such as the Marine Corps' interest in small, tactical drones and drone swarms to provide infantry organic close-air-support and reconnaissance.

Nuclear Deterrence

Drone swarm technology has significant implications for both the offensive and defensive sides of the nuclear deterrence equation.

Swarms offer new means of defeating traditional nuclear delivery systems — a defensive advantage. They could serve as novel missile defenses, potentially even against hypersonic missiles. Imagine 100,000 cheap, simple drones forming a dome over a high-value target. Any incoming missile, no matter how fast or maneuverable, would likely hit a drone (whether lightweight drones are enough to damage a reentry vehicle or throw it off course is an open question). The same drones could also serve effectively as air mines, colliding with or exploding in the vicinity of incoming bombers. Even small drones can significantly damage airplane wings. This could be especially effective against low-flying bombers because there is less airspace to cover and defenders can use short-range drones. Finally, multi-domain swarms of undersea, surface, and/or aerial drones could search the ocean for adversary submarines. The drones might locate, follow, relay information about, or attack the submarines. They also could draw information from broader sensor networks.

However, drone swarms also offer new means to improve nuclear delivery — that is, nuclear offense. States are already pursuing drone delivery systems for nuclear weapons, and drone swarms can also improve existing nuclear delivery systems without being armed with a nuclear weapon. Just as they may be able to serve as air and missile defenses, drone swarms can be used to defeat, disable, or trick those same defenses. While it's true that air and missile defenses are highly mobile, creating significant challenges for locating and destroying them, drone swarms have the advantage of being able to spread out broadly to search for them. Along the same lines, Israel used drones as decoys to trick Syrian air defenses into believing they were Israeli aircraft. Drone swarms could do the same in larger, more distributed numbers to encourage defenses to hit the drones instead of the delivery systems carrying nuclear, biological, or chemical weapons. Drone swarms would move more effectively as a unit, akin to how groups of actual aircraft would behave.

Swarms may also improve nuclear targeting. Drones can be used to collect information to identify vulnerabilities or previously unknown defenses. Traditional delivery systems such as cruise missiles, while not technically drones, might incorporate drone swarm technology to adjust their approach en route, for instance based on other systems' success or failure in striking targets. This is especially useful for counterforce strikes against an adversary's military, which hinge on accurate and comprehensive target identification and precise strikes on those targets. Improved targeting is less important for second strikes and countervalue strikes, which target cities and civilians. Additionally, more accurate weapons mean fewer warheads and delivery systems would be needed. Targeting improvements may also lower upkeep or other costs.

In this way, drone swarm technology could make nuclear delivery systems either more or less survivable, depending on who uses the technology and how. Delivery system survivability is critical to nuclear stability. A nuclear threat is less credible if the threatened state believes it can reliably defeat the nuclear system. And on the other hand, if a state believes its nuclear delivery systems can be defeated, it may develop and deploy more nuclear weapons and novel delivery systems, as well as act more aggressively in crises and conflicts. Such concerns underlie Russia's objections to U.S. ballistic missile defenses. This was also a key reason the United States and others have pursued multiple means of delivering nuclear weapons: to ensure nuclear weapons could always survive a first strike.

Will drone swarms ultimately improve nuclear offense more than they would improve nuclear defense? It's unclear. But theoretically, emerging technologies that improve the ability to defeat nuclear weapons are more disruptive to overall nuclear competition than improvements to delivery. Nuclear weapons already inflict such significant damage that delivery improvements are unlikely to fundamentally alter the character of nuclear warfare. If North Korea can significantly deter the United States with a small, simple nuclear arsenal, for instance, delivery systems improvements seem unlikely to alter the fundamental dynamic. Therefore, while drone swarm technology could aid attacking states, the improvements for defenders are likely to matter more.

Chemical and Biological Weapons Proliferation

Drone swarm technology is likely to encourage chemical and biological weapons proliferation and improve the capabilities of states that already possess these weapons. Terrorist organizations are also likely to be interested in the technology, especially more sophisticated actors like the Islamic State, which has already shown interest in drone-based chemical and biological weapons attacks. Drone swarms may also aid counter-proliferation, prevention, and response to a chemical or biological attack, but those applications appear less significant than the offensive applications.

Indeed, swarms have the potential to significantly improve chemical and biological weapons delivery. Sensor drones could collect environmental data to improve targeting, and attack drones could use this information in the timing and positioning for release, target selection, and approach. For example, attack drones may release the agent earlier than planned based on shifts in wind conditions assessed by sensor drones.

Dispersed attacks also allow for more careful targeting. Instead of spraying large masses of agent, drones could search for and target individuals or specific vulnerabilities such as air ventilation systems. This also means the drones would not need to carry as much agent.

Moreover, drone swarms enable the use of combined arms tactics. Some attack drones within the swarm could be equipped with chemical or biological payloads, while others could carry conventional weapons. Chemical or biological attack drones might strike first to force adversary troops into protective gear that inhibits movement, then follow up with conventional strikes. Although combined arms tactics are possible with current delivery systems, drone swarms allow much closer integration between conventional and unconventional weapons.

These improvements in chemical and biological delivery could conceivably weaken both the military and moral justifications for the relative marginalization of weapons in international politics (with some key exceptions). As far as military utility goes, chemical and especially biological weapons are often unreliable modes of attack. Environmental and territorial conditions such as precipitation, wind, humidity, and vegetation reduce the efficacy of the agent, while protective gear may significantly or wholly mitigate the harm they cause. But drone-based environmental sensors could make these weapons much more reliable, while combined arms tactics could mitigate the impact of, or even gain advantage from, adversary use of protective gear.

The moral opposition to chemical and biological weapons has much to do with their indiscriminate nature and the consequential risk of collateral harm. In 1968, wind blew a cloud of VX nerve agent from the Dugway Proving Grounds in Utah into a nearby farm, killing thousands of sheep. Public opposition to the event helped catalyze the Nixon administration's review of the U.S. chemical and biological weapons programs, culminating in an end to the bioweapons program. With improved targeting, including employing drone-based environmental sensors, it's possible to imagine less error-prone, more discriminate chemical and biological weapon delivery systems that might be less morally objectionable.

Of course, just because these weapons are more usable does not necessarily mean they will reemerge. Modern chemical and biological weapons emerged in a different security environment. Various international laws may constrain rearmament and significant usage, as might popular opinion or political leadership. Still, it's worth considering how advances in technology could make previously indiscriminate weapons more discriminate.

At the same time, drone swarms may also help prevent and respond to chemical and biological weapon attacks. Drone swarms could aid counter-proliferation efforts by, for example, coordinating searches for previously unknown chemical and biological facilities to secure stockpiles after a war. They could similarly coordinate searches along national borders to identify potential smuggling activity, including CBRN material smuggling, or searches through cities to search for gaseous plumes. Notably, swarms could serve as mobile platforms for chemical or biological detectors with different types of sensors to mitigate false positives. If an attack is successful, drones could coordinate mapping of affected areas to help guide responders. Drones could even have sprayers to help clean up after an attack, without risking harm to humans. But given the rarity of chemical and biological weapons attacks and the technical uncertainty of creating reliable, drone-based CBRN detectors, these applications appear less significant than the improvements to offensive capabilities.

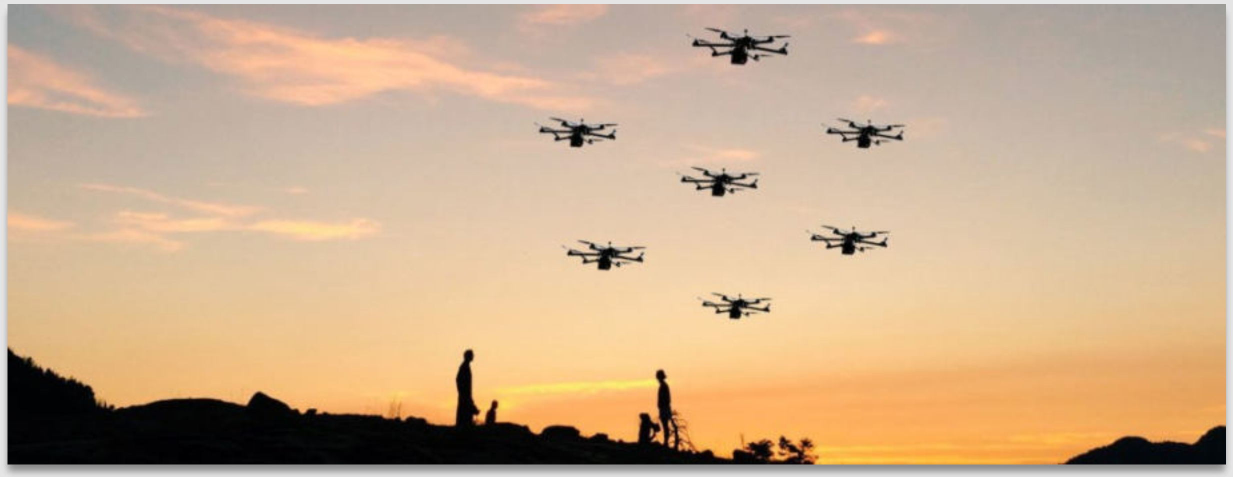
Conclusion

Several agencies have clear equities in this area and should consider how to respond to the technology's emergence. First, the Commerce Department's Bureau of Industry and Security should adopt new rules restricting the export of swarming-capable drones and related technologies. These rules should especially focus on technology with the potential to improve chemical and biological weapons delivery.

The Defense Department should expand its ongoing research and development into drone swarms to include CBRN-relevant uses. Current DoD research appears to focus on fundamental drone swarm capabilities, but not CBRN-specific applications. The department should also conduct red-team analysis to identify in which that drone swarms could support adversary capabilities in this area, especially chemical and biological weapons delivery.

The Department of Homeland Security should fund research and development into drone swarms for CBRN detection and response. This research should focus on three separate, but related lines of research: detectors, decontaminators, and platforms. Detectors and decontamination systems need to be small enough to effectively mounted on small drones. Drone swarm platforms need to effectively coordinate actions when broadly dispersed and require control systems for detectors and decontaminators.

The State Department should evaluate whether and to what extent existing international treaties are sufficient to discourage proliferation of CBRN-relevant drone swarm technology. Particularly, the department should consider whether and how to account for swarming technology in the Missile Technology Control Regime, which restricts individual drones.



Testimony

Jaikishore T S
Route Manager,
Air India Express, Mumbai

I would say, the best decision I had taken ever was to choose HICET to do my Aeronautics Bachelors course. My time at HICET positively changed who I'm and the culture practiced at HICET shaped me personally and professionally to fit to a successful position in a highly competitive corporate industry. The culture at HICET fostered the sharing of ideas, critical discussions, and collaborations among students and faculty across a wide range of interests.

HICET Aero department had got a faculty team who were experts in the field of Aeronautics and could impart their practical knowledge to us in an easily relatable way. The faculty team were more enthusiastic in giving all their knowledge to us in every possible interesting way, from organising Industry Visit to Air Force Stations, to procuring state-of-the-art lab apparatuses for us to practise. Every assignment and project activities that were given to us were curated to our specific interests in the field of Aeronautics so that we could give the best of us!

At HICET, we had access to a huge collection of books related to our academics. The best part of doing Aeronautics course at HICET is that we were given job-on-focus training, including but not limited to aptitude, communication skills etc., as a part of our curriculum. Department and HICET faculty had extended their strong support to us to reach our golas. We are really grateful for their never ending support.

I sincerely thank and humbly submit my best wishes to the Department of HICET and its amazing faculty team.

Priyanka K
Dy. Manager, Flight Line,
HAL, Bangalore

The four years spent in HICET is very precious to me. HICET moulded us to professionals and our technical and managerial skills were honed by our faculties - the amazing, friendly and dedicated experts of HICET AERO department. They made the course extra-exhilarating by giving us opportunities to identify our area of interest through innovative assignments, practicums/projects, visiting industries etc., thereby bringing the best out of us.

Field-based learning at Air Force Station and visits to top notch Aero Industries metamorphosed me from a dreamer to a doer. It kindled me to join the Forces. Though I'm not in 'Forces' now, I joined the 'Force Behind The Forces', HAL in its prestigious project, the home grown fighter aircraft, LCA-Tejas as Flight Line Engineer. Besides imparting knowledge, our faculties made us ever-ready to take on any challenges. They stood with us and also ran with us till we hit our Goal. All the staffs in HICET AERO dept. are very supportive, provided us an excellent exposure across various platforms and wanted us to explore and learn new things in terms of personal and professional aspects.

HICET and HICET Aero Department, please accept my gratitude and heartfelt thanks for helping me to realize the dreams that I dreamt as student in your classrooms. Flying high with the wings given by you. I am sure HICET will always Stand Tall and scale greater and greater heights.