SCHOOLS AEROSPACE CHALLENGE 2018

TEAM SIKORSKY

Matvey Boguslavskiy, Harry Walden, Abhyuday Luthra

Sponsor: Cathie A Wells (caw@rgshw.com) Teacher

Aerospace Engineering Challenge:

Introduction: Our aim was to come up with three initial concepts for disruptive technologies that could be integrated into the RAF, then later consolidate these into one or two more detailed final proposals. To do this we initially took inspiration from current technology used by armed forces around the world as well as other technological advantages in computer science, materials science and other rapidly developing areas. Some of the key factors that helped distinguish our final ideas from the initial concepts were: feasibility, costs, ethics and how quickly they can be deployed, among other more specific factors for each concept.

Concept A – Surveillance Drone Network

US Army Drone "Reaper"

Our first concept is a network of surveillance drones which would be launched for a few hours at a time from a command post in a hostile area. The focus is particularly on making the craft small, lightweight and low cost to minimise the impact of losing a craft. They would be able to provide high resolution and perhaps even thermal imaging of an area by using multiple cameras.

Threod Systems Mini-UAS

The idea takes inspiration from Titan Aerospace, acquired in 2014 by Google, who attempted to provide 4G signal via solar-powered drones, as well as Miniature UAV technology used by several armed forces across the world.

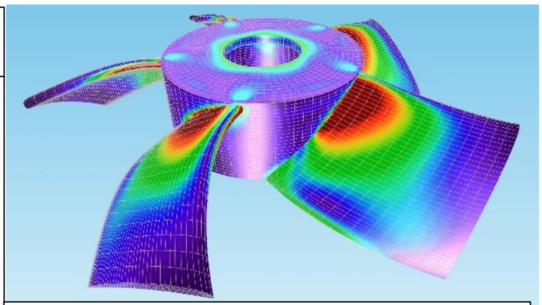
We propose combining these to create a constantly cycling network of small low-cost drones (<3m wingspan) to provide comprehensive surveillance of an area with a relatively short deployment time.

Composite imaging techniques are used to increase the resolution of images by combining multiple photos into one. This technology is already used by NASA to map the surface of Mars in great detail. The impact of this would be that the terrain of a hostile area could be accurately mapped, minimising the risk to troops in the area. We envision that our drones could also be used with a convoy of vehicles, and could potentially give the capability to detect IEDs and minefields more reliably.

The ethics of surveillance equipment are always complicated when it comes to use on civilians and the general population. However, the surveillance drones that we are suggesting are for use in hostile areas, where privacy of citizens is not considered a priority, but rather the safety of soldiers and other personnel. When in use around a base, there is really no issue with the use of this project, however when used with a convoy it can infringe on the privacy of people who live close by to where the convoy passes.

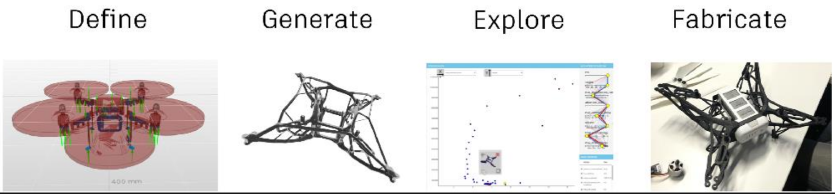
Concept B – Artificial Intelligence Aided Design

In recent years, developments in computing technology have allowed us to model aerodynamics and material stress incredibly accurately. Computational fluid dynamics and finite element analysis have undoubtedly been used by the RAF in the design of their most recent planes, but our idea is to combine this with an artificial intelligence machine learning algorithm. The advantage of using evolutionary algorithms in designing components and aircraft bodies is that they can be optimised beyond the limits of a human engineer, while requiring little to no intervention. Machine learning can produce unintuitive solutions, for example the organic shapes produced by Autodesk's Project Dreamcatcher.



An example of FEA being used to map stress.

Computer generated iterative design is already used in the automotive industry to create more aerodynamic shapes and structures with higher strength



By optimising designs in this way, the primary impact is a reduction in manufacturing costs because a lot of material can be saved. As well as this however, the improved aerodynamics and weight reduction also save a lot of fuel, which currently costs the RAF £700m a year.

A design produced by Project Dreamcatcher

Artificial intelligence is perhaps the most technologically advanced of our concepts, and as a result there is some debate about the ethics of such a creation. In relation to our concept the key issue is in assigning blame when the system fails. Should the safety of pilots and other personnel be entrusted to a computer? Or perhaps is the programmer to blame when something goes wrong? This issue is very current as self-driving cars begin to become a reality.

Concept C – Variable Wing Technology

During the Cold War, both the US and the Soviet Union developed variable wing technology, inspired by the wings of birds (left), to allow aircraft to optimise either speed or range depending on the mission, and to change mid-flight. Recently as planes became lighter and more specialised this has been phased out since the mechanism was too heavy. We propose a variation of this idea but in a more lightweight form.

An example of how this might be achieved is through the use of shape memory alloys to change the shape rather than a heavy hydraulic system. Boeing filed a patent for such a technology in 2008 and last year NASA successfully tested a small scale model using SMA variable wings. In full scale this would be 80% lighter than previous VW technology. As well as increasing fuel efficiency by reducing weight, being able to vary the wing shape for different situations could potentially increase flight time even further.

"Variable swept wings aren't dead, they just found their niche on bombers where other technologies can't quite make up for the physical ability of changing the physical geometry of the wings."

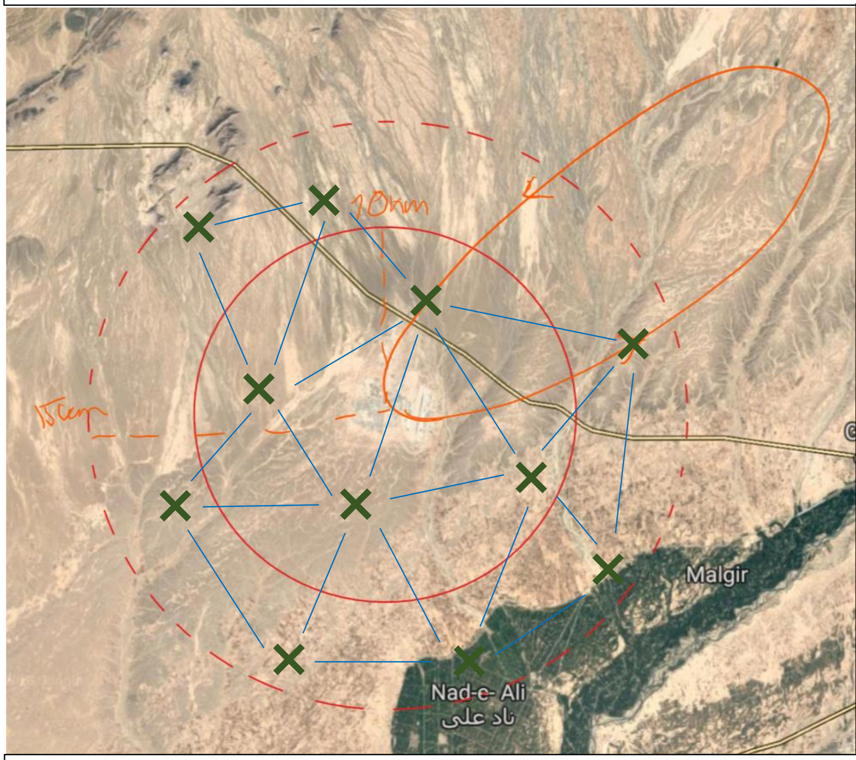
Removing the hydraulic system previously used to vary wing shape not only makes the aircraft lighter, but it also improves the aerodynamics by using a smooth continuous surface instead. Our concept could also be more functional than older VW technology since it has the potential to move in more than one direction using shape memory alloys.

The use of variable wing technology is ethically very sound in comparison to our other ideas, since it only improves the flight capabilities of an aircraft, not weapons or surveillance.

Evaluating Initial Concepts: Concept A seems to have great potential due to its quick deployment time and the flexibility within the network. Ethically this is the most questionable because of its potential for use in populated, friendly areas, however it essentially has the same function as satellite imaging but on a smaller scale. Concept B could also be very useful, but the main issue here is the deployment time. It can make massive improvements to the design of aircraft but adding on the manufacture time it simply doesn't meet the brief of "disruptive" technologies. Concept C has great proof of concept in that variable wings have been used before as far back as the 1960s, and so our idea is simply an improvement on this.

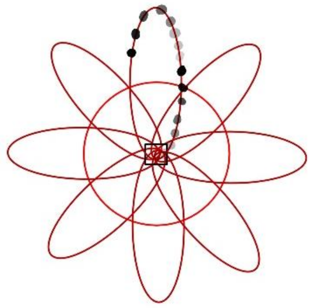
While we have produced three very feasible initial concepts, after an evaluation of the other factors involved we chose to drop the idea of machine learning in aircraft design since it likely already features in some elements as a natural extension of CFD and FEA technologies, and also because it cannot be rapidly deployed or easily integrated because entirely new aircraft must be designed from scratch.

Developed Proposal – Surveillance Drone Network



Further developing our concepts into more complete ideas, we have looked in more detail at the function of the drones and how this will affect their weight, power and flight time. Our final concept is a "swarm" which is distributed over an area up to 20 km radius from a control centre. The diagram on the left illustrates how the drones would communicate with each other to create a network. The advantage of this is that if one drone is lost (e.g. shot down or malfunctions) it does not compromise any of the others as the network remains intact. This inherent flexibility in the system means it is easy to integrate new drones and remove others as their battery gets low or for maintenance.

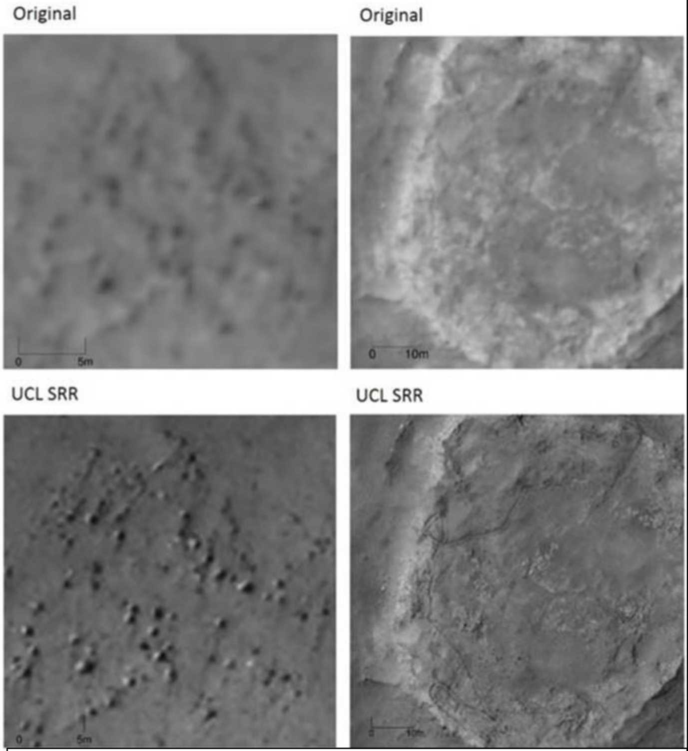
In order to maintain constant surveillance of an area, the drones would cycle in groups of four around eight ellipses to a maximum of 20 km from the control centre. In each loop only three drones are in the air at once while the fourth remains on the ground to charge. The loops are approximately 90km in perimeter and so at an average speed of 90 kph this is a one hour flight for each loop. Overall at three loops per flight this is around three hours, leaving one hour downtime on the ground. Using Li-ion batteries with spares constantly being charged this is entirely feasible.



Shown on the left is an air powered launch device used for mini-UAVs like those that inspired our first concept. This device could be mounted to a truck for use in monitoring a convoy, or on the ground for monitoring a fixed location. Some mini-UAVs can be hand launched but in order to save power we felt this would be more effective. It also minimises the human intervention needed, since larger drones currently require three or more personnel to control from the ground.

Some civilian UAVs already use images taken from multiple angles to create a 3D model of an environment- this is often used by filmmakers and video game developers to use CG images easily in realistic environments as well as by builders to monitor earth-moving needs and progress. This has been done by amateurs and professionals alike as UAV-mounted cameras become accessible.

The technology connecting all the separate UAVs can be used by civilians to rapidly make a 3D models of buildings, streets and other surroundings. However, this technology could also be used by topographical surveyors to accurately map canyons, cliffs and other potentially hazardous environments. This could allow for careful planning of journeys for infantry and civilians alike.



NASA composite imaging of Mars from HiRISE

NASA has used composite imaging to produce higher resolution images than their HiRISE satellite is normally capable of. In the examples shown, eight similar images have been combined to create a much more detailed map of Mars' surface. Ideally this level of detail will allow very small objects such as IEDs to be detected by our drone network.

A large drone such as the US military's *Reaper* would require three personnel for each drone whereas a smaller "mini" UAV needs only one or two. Since our drones follow very simple paths they can be pre-programmed and as such we expect that at most one person would be needed to monitor each one. We have also considered integrating some elements of artificial intelligence to automatically identify threats, which would raise the initial cost but reduce maintenance costs and would mean that as few as ten people could monitor the entire group of drones from a control centre, which could potentially be mobile i.e. part of a convoy.

One of the main reasons for our drones to be implemented is the relatively low cost and sustainability. They are designed to be cost-efficient so that if one or two are shot down they can be quickly replaced to maintain the integrity of the network. Similarly the network is laid out in a way the ensures each drone is linked to at least two others, ensuring the chain remains unbroken even in the event of losing a drone.

The approximate costs of a drone are as follows:

- Basic drone, controls and video transmission **£2000**
- 1080p HD camera **£400**
- HD thermal camera **£3000**
- 1.2kg Li-ion batteries **£200**
- Hydrogen fuel cells of same power **£100**

Not every drone will necessarily be equipped with a thermal camera, that could change depending on the mission. Also it is important to note that these costs are for commercial parts and so these might not be suitable for use in a warzone. We might allow for additional costs of up to £1000 for bringing the drones up to military standards. Both lithium-ion and hydrogen cells are included in the list but only one would be equipped on the drone. Hydrogen cells are slightly cheaper but heavier and more dangerous to use since hydrogen is flammable, but there are no harmful emissions. Li-ion cells take time to recharge but are safer. Overall the cost of a single drone would be between £5,000 and £10,000 dependent on the configuration of the drone e.g. thermal camera.

Another benefit of the drones is the short production time. Based on other mini-UAVs we estimate that they would take roughly a week per drone for manufacture. We have also explored the idea of 3D printing the drone. This would allow us to use a cheaper material, a plastic polyamide, but it would massively extend the production time which brings yet more costs. While this is perhaps unfeasible, 3D printing could be ideal for quickly producing spare parts on site.

Conclusion: Having started with three initial concepts we narrowed our focus onto the one we felt best met the brief of 'disruptive technologies'. Both AI-aided design and variable wing technology would have taken too long to implement, whereas drones are ideal as a rapid response. We believe they are an effective and sustainable method of surveillance in hostile areas and make use of technological advances which have already proven useful in other industries.