HELIKITES FOR HIGH-ALTITUDE RADIO-RELAY
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1) INTRODUCTION

Military communications using high frequency radio waves are becoming more and more important as the advantages to the warfighter of ready access to digitally transmitted data such as visual maps, GPS locations, text messaging and video images become apparent. Digitisation allows radio traffic to differentiate between numerous manned and unmanned vehicles, giving a vast new unmanned force to those who learn to how to exploit this potential.

However, a problem emerges when high frequency radio waves are used. The user discovers that high frequency radio waves travel in straight lines whereas terrain does not. Also, higher frequency radio waves are attenuated to a greater extent by trees, hedges and buildings than lower frequency waves. In practice, a radio signal that might travel twenty miles over the sea may well only travel one mile from person to person in rolling countryside. This is a huge problem, and one that the governments of the world have spent millions of dollars trying to overcome. The answer has been found in sophisticated types of radio-relay. The problem that remains is the positioning of large numbers of radio-relays when required, in the right place, easily and cheaply. The solution to this is fundamental to the progress of military radio communications. This paper will out-line the potential bandwidth gain using an ideal platform and the problems with present radio-relay platforms that presently frustrate that bandwidth gain. It will then explain the potential of the latest tethered Helikite aircraft to provide a reliable airborne platform and outline the recent work done in this field. It will then show how simple it is to create robust, long-range aerial internet-protocol ad-hoc networks for the military and explain the significance of these networks for the future.

Picture 1. A three cubic metre, 10ft long, Skyhook Helikite carrying ITT SpearNet MANET Radio.

2) POTENTIAL BATTLEFIELD GAIN

a) Greatly increased radio comms range. In perfectly flat terrain or at sea, warfighters with an antenna at 6ft in height have a radio-line-of-sight (LOS) of 6 miles, which gives a 113 sq mile comms area. Research has shown that VHF and UHF radio-relay units lifted to 1,600 ft on small, instantly-fielded Helikites can provide high bandwidth, IP protocol, radio-relay out to 60 miles in flat terrain. This gives a comms area of 11,311 square miles. Which is over 100 times the area.

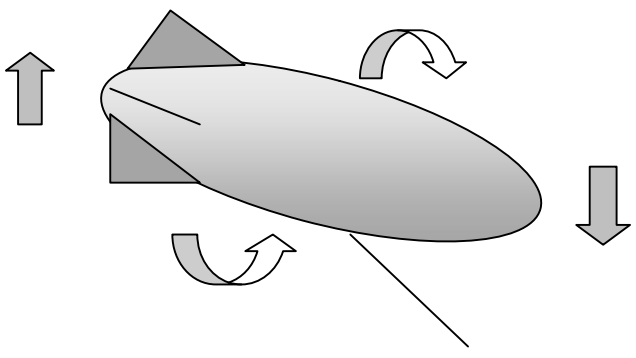
b) Fully networked comms. MANET radio comms are excellent if the radios and sensors are within line-of-site of each other. In practice, radios deployed on vehicles or troops are usually too low to connect correctly, especially on the move. This is exacerbated by the fact that some MANET radios fail to pass high-bandwidth information beyond 5 “hops”. This has severely restricted the uptake and exploitation of extremely useful MANET sensor technology. Helikite raised MANET radio-relays overcome this problem as they give excellent coverage and reduce the “hops” required.

c) Full broadband communications to each warfighter. A fully functioning internet protocol MANET system allows each warfighter to send and receive internet access, streaming video, high-bandwidth downloads, text-messages, e-mail, etc. This can be done on the move and when in hiding.
d) Full real-time streaming video from unattended ground sensors. Simple information from UGS can be sent via satellite. However simple information is often unclear or unreliable. Also, simple information can be exploited by the enemy to confuse or trap their adversaries. Walking around and around a footfall-sensing UGS will cause the simple sensor to indicate a large force is in the area. A helicopter sent in to attack the force may then be ambushed by the enemy. This was a common tactic by the Vietcong. Real-time video from a sensor relaying via a high-altitude Helikite eliminates this problem and gives far greater information in all situations. Video cameras can be monitored and controlled from anywhere in the world. Video information received can be computer analysed to save manpower.
e) Ground-to-air comms to low-flying manned aircraft. Presently ground troops cannot talk directly to the pilots flying low-level close air support until the aircraft is within about 60 seconds of the target. This leaves little time to plan an attack. Helikite lifted airborne relays can contact the aircraft while it is still scores of miles away, leaving plenty of time to send the aircraft data, maps, target details, and voice information. This will improve close-air-support and reduce fratricide.
f) Communications to unmanned vehicles. Unmanned vehicles are hugely restricted by lack of beyond-line-of-sight (BLoS) radio communication. Presently, the military is waiting for autonomy to deal with this problem, but it will be decades, or possibly even centuries, before quantum computers appear capable of understanding context – which is required for combat. Airborne Helikites can easily relay to low-flying UAV's, UGV's in urban areas and USV's at sea. Helikite radio-relays immediately enable massive unmanned assets to be used to save lives, win battles and combat terrorism.

3) CHARACTERISTICS OF PRESENT MILITARY RADIO-RELAY PLATFORMS

A perfect military airborne platform would instantly send any number of these radio-relays up to suitable altitudes, whenever and wherever bandwidth was required. The only reason this does not happen now, is because most of the airborne radio-relay platforms presently fielded by the military are very expensive per hour and per square mile, but still leave a lot to be desired in terms of payload, altitude, endurance, ease of use, all-weather ability, safety and cost. Line-of-site communications are dependent upon a) the radio equipment and b) the platform. So a full understanding of the performance of the platforms is as important as a full knowledge of the radios. In brief, the relevant problems in relation to the potential coverage area over time are:

Radio trucks with masts. Small coverage area. Personnel very vulnerable.
Satellite. Very expensive. Low bandwidth. Unavailable in forests and urban canyons. Slow to field. Satellite positions are all known and predictable so they are very vulnerable to anti-satellite systems.
Manned aircraft. Expensive. High wear. Place valuable pilots at high risk. Vulnerable. Fuel hungry.
Unmanned aircraft. Low endurance. Expensive. High attrition. Low bandwidth. Need pilots.
Traditional tethered blimp aerostats. Too big to handle easily. Fair weather. Expensive. Bad ground handling. Excessive helium. Low altitude. Expensive. Unstable in high winds:



Traditional blimps are unstable in high winds.

High winds push the fins of blimp aerostats upwards. This in turn causes the nose to drop and twist, causing unstable and dangerous movements called **"Porpoising".**

Unmanned ground vehicles. Too low. Too many needed to create network. Expensive. Vulnerable.
Numerous scattered ground MANET relays. Far too close to the ground. Very high attrition. Need thousands to create a reliable MANET. Expensive per square mile.
Free floating balloons. Excessive attrition. Fair weather. Move out of station fast. Expensive. Too high.
Helikites. Easy to use. High altitude. Persistent. Reliable. Versatile. Minimal manpower. Inexpensive.

OPTIMUM RADIO-RELAY PLATFORM REQUIREMENTS	HELIKITE	MAST	SATELLITE	MANNED AIRCRAFT	UAV	BLIMP	UGV	FREE BALLOON	GROUND RELAYS
High Payload	✓	✓		✓	✓	✓	✓		
Wide Area Coverage	✓		✓	✓	✓	✓		✓	
Optimum Altitude	✓			✓	✓	✓			
Extreme Duration	✓	✓	✓			✓	✓		
Ad-Hoc Network Friendly	✓	✓			✓	✓			
Safe for Operators	✓		✓		✓	✓	✓	✓	✓
Low Attrition Rate	✓	✓	✓						
Instant Deployment	✓	✓		✓	✓		✓	✓	✓
All-Weather Operation	✓	✓	✓	✓			✓		✓
All-Weather Deployment	✓	✓		✓			✓	✓	✓
Autonomous Operation	✓	✓	✓			✓		✓	✓
High Technology Security	✓	✓	✓			✓			
Small & Easily Handled	✓				✓		✓	✓	✓
Single Person Deployment	✓	✓					✓	✓	✓
Invisible at High Altitude	✓		✓		✓			✓	
Inexpensive Relay Coverage	✓								
Air Traffic Friendly	✓	✓	✓			✓	✓	✓	✓
Free of Radio Interference	✓	✓	✓			✓		✓	
Radar Stealthy	✓				✓			✓	✓
Tough	✓	✓					✓		✓
Expendable	✓						✓	✓	✓
Minimal Training	✓							✓	✓
No Fuel Required	✓	✓				✓	✓	✓	✓
Deployable from Aircraft	✓			✓			✓	✓	
Widely Available	✓	✓		✓		✓			
Established Technology	✓	✓	✓	✓		✓			
Worldwide Operations	✓	✓	✓	✓		✓			

Table 1. Characteristics of present radio-relay platforms

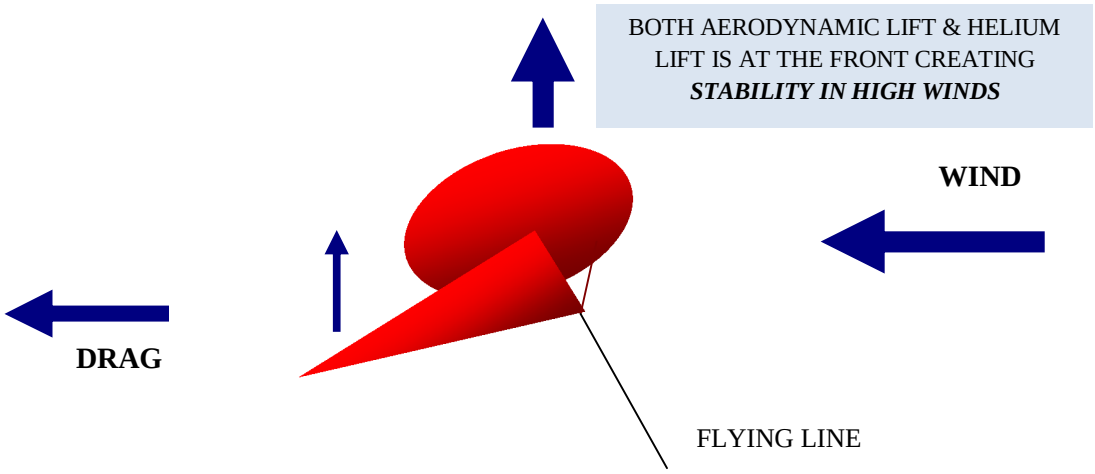
4) CHARACTERISTICS OF POTENTIAL FUTURE RADIO-RELAY PLATFORMS

Giant unmanned stratospheric Zeppelins. Appalling ground handling. Vulnerable. Hugely expensive. Excessive helium.
Solar powered stratospheric UAV's. Delicate. Research stage. Expensive. Fair weather launch and recovery.

5) CHARACTERISTICS OF HELIKITES

Table 1 shows that Helikites would fill the present radio-relay platform capability gap. Stealth Helikites are low-visibility versions of Skyhook Helikites. They are tiny, novel, lighter-than-air tethered aircraft. They fly night and day, in all-weathers. Helikites are autonomous & have no noise or thermal signature. Translucent & flying at altitudes way above small arms fire, Stealth Helikites are very hard to see in daylight & invisible at night. Deployed in seconds from Humvees, tents, heli-bases, boats or rooftops they can fly unattended for weeks at altitudes of thousands of feet. They cost only a few dollars a day to maintain so they can be fielded indefinitely for minimal cost.

Diagram 1. **THEORY OF HELIKITE FLIGHT**



Helikites are true tethered aircraft not balloons. Helikites are pushed up by the wind, rather than downward like normal blimps. Therefore Helikites do not need large volumes of helium to combat the wind. So all-weather Helikites are far smaller than blimps and fly at many times greater altitude.

HELIKITE SPECIFICATIONS

HELIKITE TYPE	VOLUME CUBIC METRES	LIFT IN NO WIND Kg	LIFT IN 15 MPH WIND Kg	MAX. WIND SPEED MPH	MAX. ALTITUDE Ft	LENGTH Ft
Lightweight Helikite	0.16	0.06	0.18	25	1300	4.1
Skyhook Helikite	1.0	0.3	1.0	35	2000	7.3
Skyhook Helikite	1.6	0.5	2.0	35	2,500	8.0
Skyhook Helikite	2.0	1.0	3.0	35	3,000	8.5
Skyhook Helikite	3.3	1.1	4.5	36	4,000	9.0
Skyhook Helikite	6.0	3.0	8.0	40	5,000	10.0
Skyhook Helikite	11.0	5.5	12.0	45	7,000	12.0
Skyhook Helikite	16.0	8.0	18.0	40	9,000*	13.0
Skyhook Helikite	24.0	10.0	30.0	50	8,000*	15.0
Skyhook Helikite	34.0	13.0	40.0	55*	9,000*	21.0
Skyhook Helikite	64.0	30.0	70.0	60*	10,000*	28.0
Skyhook Helikite	120.0	60.0	140.0*	70*	11,000*	40.0

Note: Figures marked with an asterix* are calculated estimates

6) HELIKITE DEPLOYMENT

Helikites can be transported, inflated and launched by one person in any weather. No adjustment is necessary. The procedure is as follows: 1) Tie the Helikite tow-loop to the flying line.2) Insert the carbon-fibre spine. 3) Inflate the Helikite with helium until the cord around the balloon is tight.

Picture 2. Three cubic metre Skyhook Helikite operating from a hole dug into the ice in Antarctica.

Picture 3. Photo taken from a 1.6 cu metre Helikite, flying at 200ft from a 15ft boat on Teahupoo surf, Tahiti.

Picture 4. 2.0 cu metre Helikite flying from a 11ft dinghy in Mexico, to lift a video camera.

Manual or electric winches are used to raise or lower the Helikite. Radio equipment is strapped to webbing loops at the top of the keel. Antenna can be positioned anywhere convenient.

7) WORLD HELIKITE DEPLOYMENT AND EXPERIMENTAL RADIO-RELAY WORK

Helikites are especially relevant to ad-hoc networks because holding relays steadily at specific altitudes strengthens the network & improves transmission quality by reducing hops without swamping the relay. One ad-hoc radio lifted to 2000ft on a 7ft Stealth Helikite provides greater relay coverage than 100 ground based radios. A significant cost saving. Regaining any lost transmissions can be achieved by raising the Helikite radio-relay. This provides broadband internet protocol communications to troops in low-lying areas & also empowers unmanned vehicles to operate in areas presently out of their reach due to terrain. Numerous scientific and military organisations have tested the Helikites' ability to greatly increase radio range consistent with predicted link-budgets in all weathers and terrains. Examples include:

1993 onwards. RSGB Peter Bubb Tech. Dir RSGB & Bob Marshall-Read, Military Communications Engineer. Used a 0.13 cu metre Jungle Marker Helikite to contact Chile from England on 10dB using 3 just Watts of power.

1994 onwards. British Antarctic Survey regularly using 3.3 cu metre Skyhook Helikites to lift radiosondes up to 3000ft through catabatic winds for measuring weather conditions at Halley Base in the Antarctic and also in the Arctic in 2008.

1998 Singapore Signals Regt., Singapore jungle - 1 x 3 cu metre Skyhook Helikite used to lift coaxial cable plus standard military whip antenna to increase UHF/VHF radio range from 2 miles to 25 miles. Very clear signals.

1999 CECOM: US Dept. of Defence, USA: Used a Stealth Helikite of 7 cu metres to study the feasibility of lifting pseudolites to counter jamming of the satellite GPS network. CECOM concluded that it was feasible and reasonable.

2002 US Air Force: Eglin A.F. Base commissioned the production of the first 60 cu metre Skyhook Helikite to lift 8Kg of radio-relay equipment to 5000ft for the purposes of radio-relay to over-the-horizon test missiles in the Gulf of Mexico.

2002 Brunei: British Army Jungle Warfare Trails Unit approved the use of 0.13 cu metre Jungle Marker Helikites for visual marking and for lifting long-wire-aerials up through the jungle canopy and into the high winds above it.

2003 Sandia National Laboratories, New Mexico, USA: 1 x 7 cu metre Skyhook Helikite. Successfully relayed video images and control data to and from an unmanned ground vehicle.

2004 Maj. David Worden, Royal Signals, UK: Cranfield University M.Sc. Project. He used a 3 cu metre Skyhook Helikite to lift coax cable plus antenna to 200ft to test the reception in the surrounding area. Then he compared the results to the theoretical computer model at Blandford. Results: Excellent propagation and very good matching to the Blandford model. The model predicted that two Helikites - each at 600ft would give high quality VHF/UHF comms. See Figure 1. The paper concluded that Helikite lifted antennas should be considered as a useful additional asset for certain military communications.

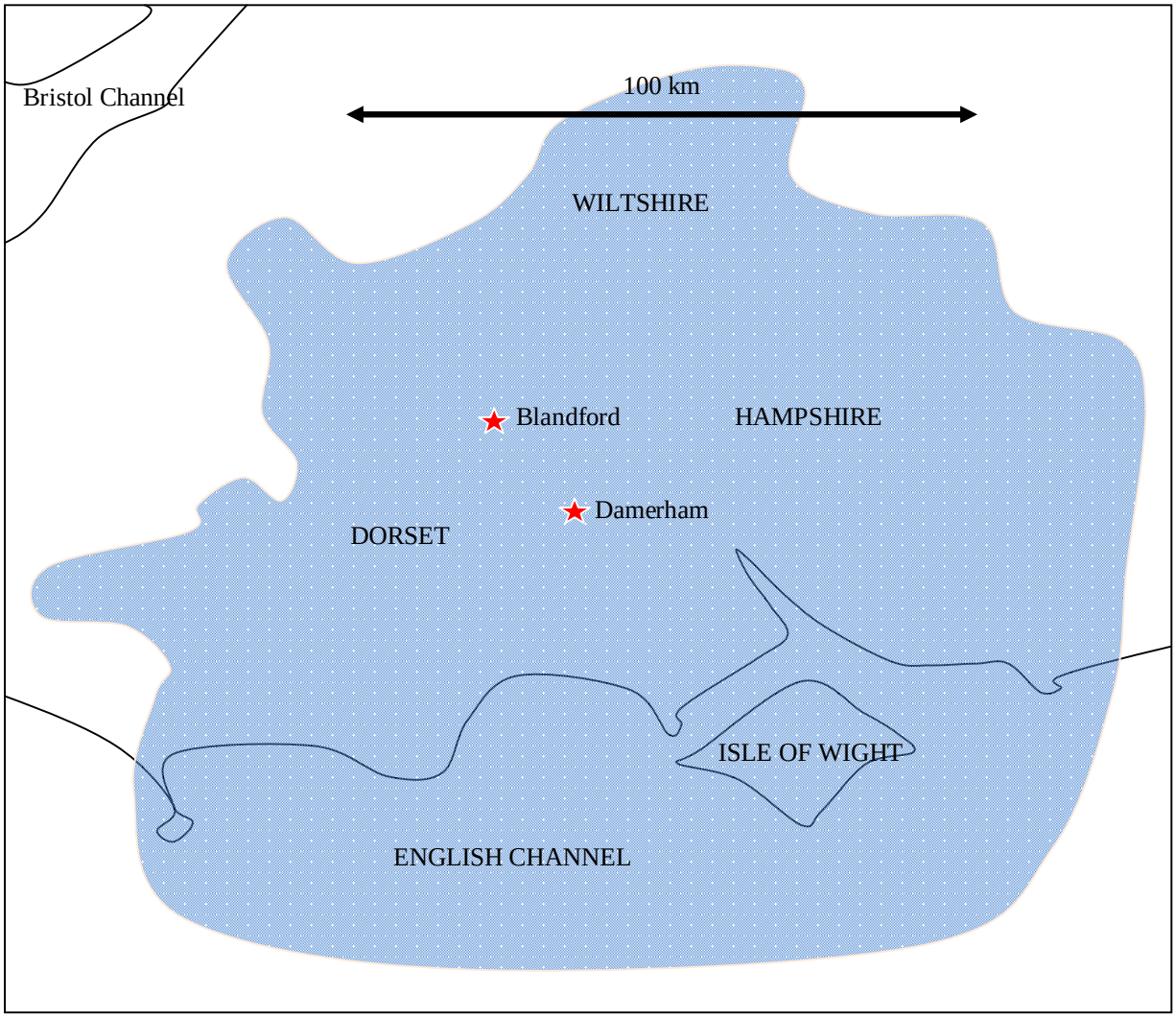


Figure 1. Radio coverage from 3Watt radio-relays lifted to 600ft at Blandford and at Damerham.

2005 Norwegian Defence Research Establishment: Norwegian mountains. Use a 16 cu metre Skyhook Helikite to lift re-broadcasting equipment over mountainous country. Good results in difficult catabatic winds.

2006 Sandia National Laboratories, New Mexico, USA: A 34 cu metre Skyhook Helikite lifts radio-relay for a Mobile Rapid-Reaction Emergency Comms Helikite Station. (Picture 5).

Picture 5. Thirty four cubic metre Skyhook Helikite deployed to 1500ft within 20 minutes in all-weathers.

Picture 6. Three cubic metre Stealth Helikites deployed on HUMVEES in California.

Picture 7. Six cubic metre Helikite ready to launch from a Helibase placed on the stern of an arctic research vessel.

2007 CENETIX, Dept. Of Defence, California, USA: Used small Helikites ranging from 1 cu metre to 6 cu metres to test the feasibility of using them to lift MANET radio-relays. HUMVEES were fitted with small electric winches and modified with Helibases so Helikites could be launched and retrieved autonomously whilst on the move (Pictures 6). Good radio-relay results achieved.

2007 US Navy, White Sands Missile Range and Monterey Naval Base: Tested 11 cu metre Skyhook Helikites lifting radio-down linked gyro-stabilised video cameras to 1,500ft altitude for the US Marines. Very good, stable video received on the ground.
2008 ITT PLC in collaboration with Allsopp Helikites Ltd, Hampshire, England: A 3.3 cubic metre Low-Visibility Helikite raised a "SpearNet" MANET radio. The coverage was increased by 100 times compared to ground-based radios.
2008 British Aerospace PLC in collaboration with Allsopp Helikites Ltd, Hampshire, England: A Personal Role Radio relay sent up to 1000ft on a 3.3 cu metre Skyhook Helikite to test urban comms. Gave excellent comms in the urban areas.
2008 US Forest Fire Department: Operated a 34 cu metre all-weather Skyhook Helikite to lift 6Kg of radio-relay equipment to enable comms from remote valleys in the USA.
2009/10 UK MOD Personal Role Radio Range Extension Trials: Large two-part trial involving around 20 people and run by Siemans and British Army ITDU Warminster. A comparison of a mast, a UAV and a Helikite for 100mW, 2.4GHz UHF relay. Realistic scenarios enacted by roaming personnel. The trial was co-ordinated with the 5 Watt man-pack Bowman Radio. Results: The mast was too low. The UAV moved about too much and repeatedly crashed or failed to take off. The Helikite was the ***only*** platform that performed satisfactorily. The 100 mW Helikite relay far outperformed the 5W Bowman.
2010 UK MOD Deployment of a 34 cu metre Desert Star Helikite plus radio-controlled Gyro-camera to Afghanistan. Operated at Baghran airbase. Successful trial leading to further orders. In fact the equipment exceeded specifications, because the approved Helikite radio downlink was so dominant it blanked out the video signal from American UAV's flying nearby.
2010 Rajant Corporation in collaboration with Allsopp Helikites Ltd, Hampshire, England. Created an airborne Mobile Ad-Hoc Network using a 1Kg Rajant "Breadcrumb" lifted on a small 9ft long Desert Star Helikite flying at 500ft. operated a PTZ camera and relayed full streaming video 6 miles.
2010 European Military Research. Radio-Relay to Unmanned Surface Vehicles using sea-borne Helikites. Helikites operated successfully from ships and boats. Ongoing research. Successful to date. (Pictures 7 and 8)

8) CONCLUSION

Numerous high-altitude, all-weather Helikites lifting MANET relays create an extensive area in which there is full broadband radio communications for personnel, sensors and unmanned vehicles. This is limited only by the numbers of Helikites and radios available.

Helikites provide a simple, viable way of greatly increasing military radio-range and bandwidth at very little cost. No extra troops or inter-service co-operation are required. Helikites are significant troop multipliers that can immediately reduce exposure to risk for personnel so reducing casualties.

Ultimately the Helikites' greatest virtue is its ability to allow warfighters far removed from the battlefield to directly help their colleagues on the ground or at sea via the remote operation of unmanned vehicles and sensors. Helikites plus MANET radios allow a vast, previously untapped, worldwide network of millions of human and computer resources, to be concentrated into the centre of the battlefield in an instant. This is force-multiplication on an industrial scale.

Picture 8. Helikite flying from research vessel to provide long-range USV relay.