HELIKITES FOR HIGH-ALTITUDE RADIO-RELAY

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Company: Allsopp Helikites Ltd,
Unit 2, Fordingbridge Business Park, Ashford Road, Fordingbridge, Hampshire. SP61BD. England
Point of contact: Sandy Allsopp. Managing Director.
www.allsopphelikites.com E-Mail: info@helikites.com

1) INTRODUCTION

Military digital 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 charts, GPS locations , text messaging and video images become apparent. Sensors relying on digital comms can protect fleets from missile attack, clear minefields and track submarines. Significantly, digitalisation now also allows radio traffic to differentiate between numerous unmanned vehicles, giving a vast new unmanned force to those who learn to how to exploit this potential. The possibilities afforded by the ability to control vast numbers of radio-controlled kinetic assets via digital radio links make it essential that fleets do not find themselves in hostile digital radio territory because the enemy could then direct any number of missiles, torpedoes, mines, submarines, unmanned boats and UAV's at no risk to themselves. It is fair to say that the operation of a fleet is unlikely to be viable for long unless it controls the electro-magnetic spectrum around it at all times.

However, a problem emerges when high frequency radio waves wish to be exploited. The user discovers that these types of radio waves travel in straight lines whereas the Earth is curved which therefore shields transmitters and receivers from each other resulting in loss of signal. Radio line-of-sight is required. Also, high frequency radio waves are normally attenuated to a greater extent by vegetation, buildings, waves, salt spray and precipitation than lower frequency waves. It is found that the movement of small boats into wave troughs and irregular movements of antennas reduces the theoretical radio range considerably. In practice, a broadband high-frequency radio signal that could theoretically travel 30 NM may in fact only be received reliably 10 NM away. The double-headed answer to this problem is to design excellent digital radio relays and then to permanently position them at high altitude. The radio-relays now exist in the form of MANET radios and small cell-phone base stations. The problem that remains is the positioning of these relays at useful altitude, when required, in the right place, easily and cheaply. This is a huge problem, and one that the navies of the world have spent billions of dollars trying to overcome.

The solution to this high-altitude positioning problem is fundamental to the progress of high bandwidth military radio communications. This paper will:
1) Discuss the characteristics of existing radio-relay platforms
2) Explain the potential of the latest tethered Helikite LTA aircraft
3) Outline the radio-relay work done with Helikites.

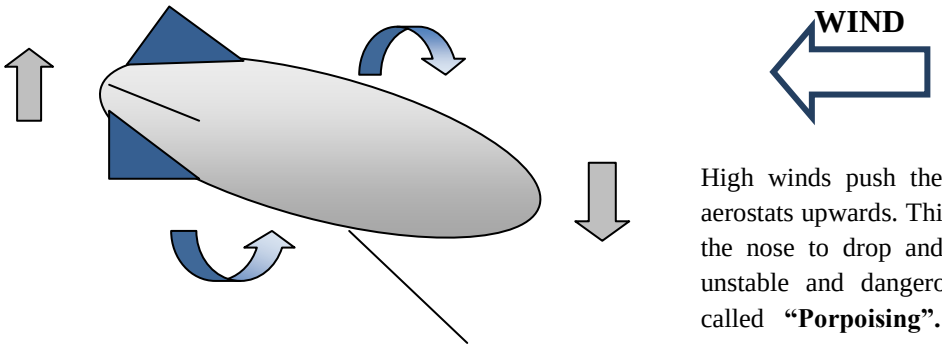
3) CHARACTERISTICS OF POTENTIAL MILITARY RADIO-RELAY PLATFORMS

A perfect military airborne platform would instantly send any number of radio-relays up to suitable altitudes whenever and wherever bandwidth was required. However, all the usual airborne radio-relay platforms are very expensive for bandwidth per hour, 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 equally dependent upon a) the radio equipment and b) the platform. So a full understanding of the performance of the airborne platforms is as important as knowledge of the radios.

Masts. Reliable, long endurance and familiar. High bandwidth. Relatively small coverage area which is too limited for over-the-horizon unmanned operations. Personnel are very vulnerable as the mast becomes a target when broadcasting radio signals. Ships with masts have to go close inshore to operate minesweeping USV's and so become a target for significant enemy fire.
Satellite. Excellent coverage where present. Very expensive. Low bandwidth. Often unavailable in many regions such as jungle, ravines etc. Slow to field. Satellite positions are all known and predictable so they are vulnerable to anti-satellite missiles, jamming or lasers.
Manned aircraft. Good coverage when present. Good payload. Low endurance. Very Expensive. High wear. Place valuable pilots at high risk. Vulnerable. Fuel hungry. Space hungry on aircraft carriers. Complex air traffic problems. Aircraft becomes a target when in flight.
Unmanned aircraft. Often difficult to deploy. Small ones that can be operated from small ships are relatively low endurance. Expensive. High attrition. Low bandwidth. Unreliable radio-relay. Constantly changing position and altitude of radio relay, which in practice is very annoying. Need highly trained ground based pilots. Difficult to maintain. Potential damage to ships when landing. UAV's often require almost as much bandwidth as they create. Complex air-traffic problems. Sense and avoid problems.
Traditional tethered blimp aerostats. Long endurance. High bandwidth. Medium altitude. Too big to handle easily onboard ship. Fair weather. Expensive. Dangerous ground handling. Excessive helium. Low altitude. Expensive. Unstable in high winds. Minor air-traffic problems.

Diagram 1.

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".**

Net-Curtain Balloons. Cheap. Simple technology. Fair weather only. Very unstable in high winds.
Unmanned surface vehicles. Long endurance. Easy to deploy and will be useful for point-to-point radio-relays but are too low to easily and quickly create a large radio-relay area of influence. Therefore many USV's are needed to create large network. Expensive. Vulnerable.
Numerous scattered floating MANET relays. Antenna too low. Very high attrition. Thousands needed to create a reliable MANET. Expensive. Moving and uncontrollable once deployed. Vulnerable.
Free floating balloons. Excessive attrition. Fair weather. Move out of station fast. Expensive. Too high.
Helikites. Easy to use from ships, boats and USV's. Can be deployed remotely. High altitude. Persistent. Reliable. Versatile. Minimal quickly-trained manpower. Inexpensive. Require some space onboard ship. Limited in height by tether. Minor air-traffic problems.

CHARACTERISTICS OF AIRBORNE RADIO-RELAY PLATFORMS

OPTIMUM RADIO-RELAY PLATFORM REQUIREMENTS	HELIKITE	MAST	SATELLITE	MANNED AIRCRAFT	UAV	BLIMP	USV	FREE BALLOON	FLOAT RELAYS	NET BALLOON
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

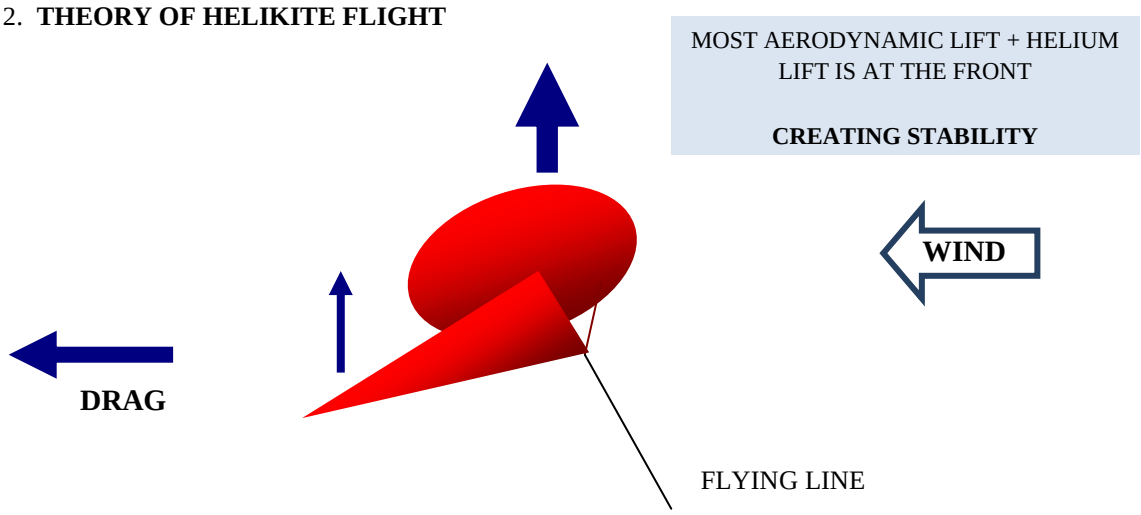
Giant unmanned stratospheric Zeppelins. Appalling ground handling. Vulnerable. Hugely expensive. Excessive helium. Recent crash, in fair weather, during maiden flight of the latest Lockheed version.

Solar powered stratospheric UAV's. Potentially useful in the future. Delicate. Research stage. Expensive. Fair weather launch and recovery. Cannot be deployed from ships at present. Not versatile or fast to deploy.

5) CHARACTERISTICS OF HELIKITES

Table 1 shows that Helikites would satisfactorily fill the present radio-relay platform capability gap. Helikites are small, 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, Helikites are often very hard to see in daylight & invisible at night. Deployed in a few minutes from shores bases, vehicles, small boats or ships, Helikites can fly unattended for weeks at altitudes of thousands of feet. They cost only a few pounds per day to maintain - so they can be fielded indefinitely for minimal cost.

Diagram 2. **THEORY OF HELIKITE FLIGHT**



Helikites are true tethered aircraft not balloons, because they 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. The best type of Helikite for harsh maritime use has proved to the tough, double-lined, Desert Star Helikite originally produced for the British Army for use in Afghanistan.

DESERT STAR HELIKITE SPECIFICATIONS

VOLUME CUBIC METRES	NET LIFT IN NO WIND Kg	LIFT IN 15 MPH WIND Kg	MAX. WIND SPEED MPH	MAX. ALTITUDE Ft	LENGTH Ft
5	1.5	4.5	40	2,000	10.0
10.0	4.0	12.0	45	3,000	12.0
15.0	7.0	21.0	47	3,500	13.0
22.0	10.0	30.0	50	4,000	15.0
34.0	14.0	45.0	55	4,500	21.0
64.0	30.0	70.0	60	5,000	28.0
75.0	35.0	80.0	65	5,500*	31.0
100.0	60.0	140.0*	70*	6,000*	35.0

Table 2. Desert Star Helikite Specifications. Note: Figures marked with an asterix* are calculated estimates because nobody has ever wanted to go that high yet.

6) HELIKITE DEPLOYMENT

Using Allsopp Helikites' unique "Helibase" system plus dedicated winch, Helikites can be safely and easily inflated and launched, by one person, in any weather, from any platform, on land or sea. No adjustment of the Helikite is necessary whatever the weather conditions. Gasoline, diesel or electric winches are used to raise or lower the Helikite. Helikite Trailer-Launchers are also available from Allsopp Helikites Ltd. These allow very rapid deployment anywhere on land. Also the trailer can be taken onto a ship. The Helikite can be towed at speed at height behind its trailer which is excellent for patrol work.

Radio equipment is easily strapped to webbing loops at the top of the Helikite keel. Antenna can be positioned anywhere convenient.

7) WORLDWIDE HELIKITE RADIO-RELAY OPERATIONS

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 RSGB Peter Bubb Tech. Dir RSGB Used a 0.13 cu metre Jungle Marker Helikite to contact Chile from England. He achieved a clear 10dB contact using 3 just Watts of power from a vehicle.

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. Launch system designed to operate from small barges.

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.

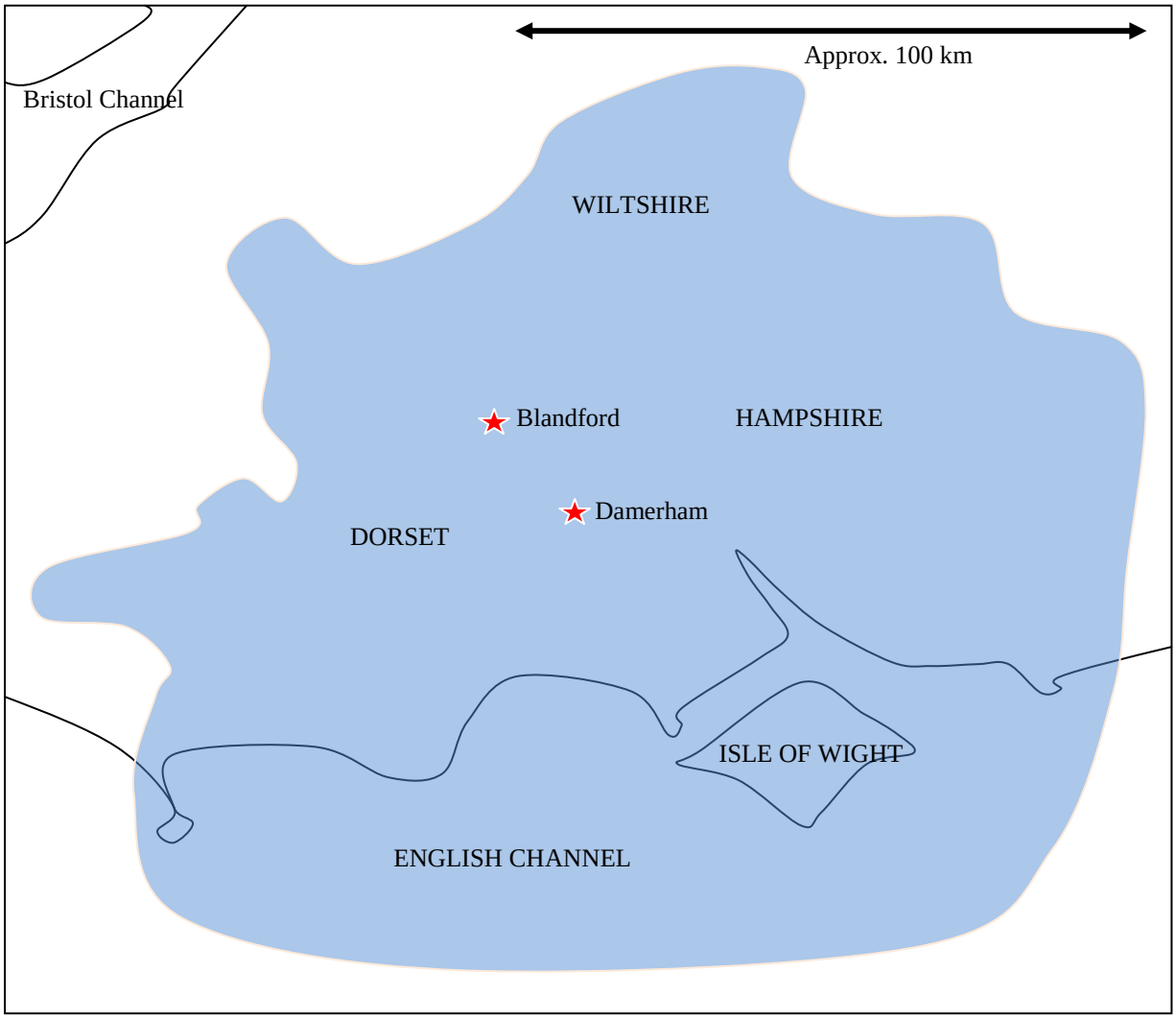


Diagram 1. Radio coverage from 2 x 3Watt radio-relays lifted to 600ft at Blandford and at Damerham.

2005 SINTEF 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 plus Ops Trailer to procured, to provide radio-relay for a Mobile Rapid-Reaction Emergency Comms Helikite Station, to protect nuclear missile convoys in case of a terrorist attack.

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 to lift radio-controlled and radio-down linked gyro-stabilised video cameras. 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 tiny 100mW Personal Role Radio relay was sent up to 1000ft on a 3.3 cu metre Skyhook Helikite to test urban comms. Gave excellent comms out to 6 miles.

2008 US Forest Fire Department: Aquired a 34 cu metre all-weather Skyhook Helikite to lift 6Kg of radio-relay equipment to enable comms from remote valleys in the USA. The Helikite is housed in a fast-response trailer that is operated by just one man.

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 the widely-spaced roaming personnel. The trial was designed to be 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 100mW PRR relay on the Helikite gave far better comms than 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 when first fielded the British Army approved-frequency 2W Helikite radio downlink was so dominant it blanked out the video signal from American UAV's flying nearby. Obviously, the radio frequencies should have been co-ordinated better from the start, but as an early example of unmanned EW, we considered this a very positive result as it shows that airborne Helikites can be used to bring down or take control of hostile UAV's.

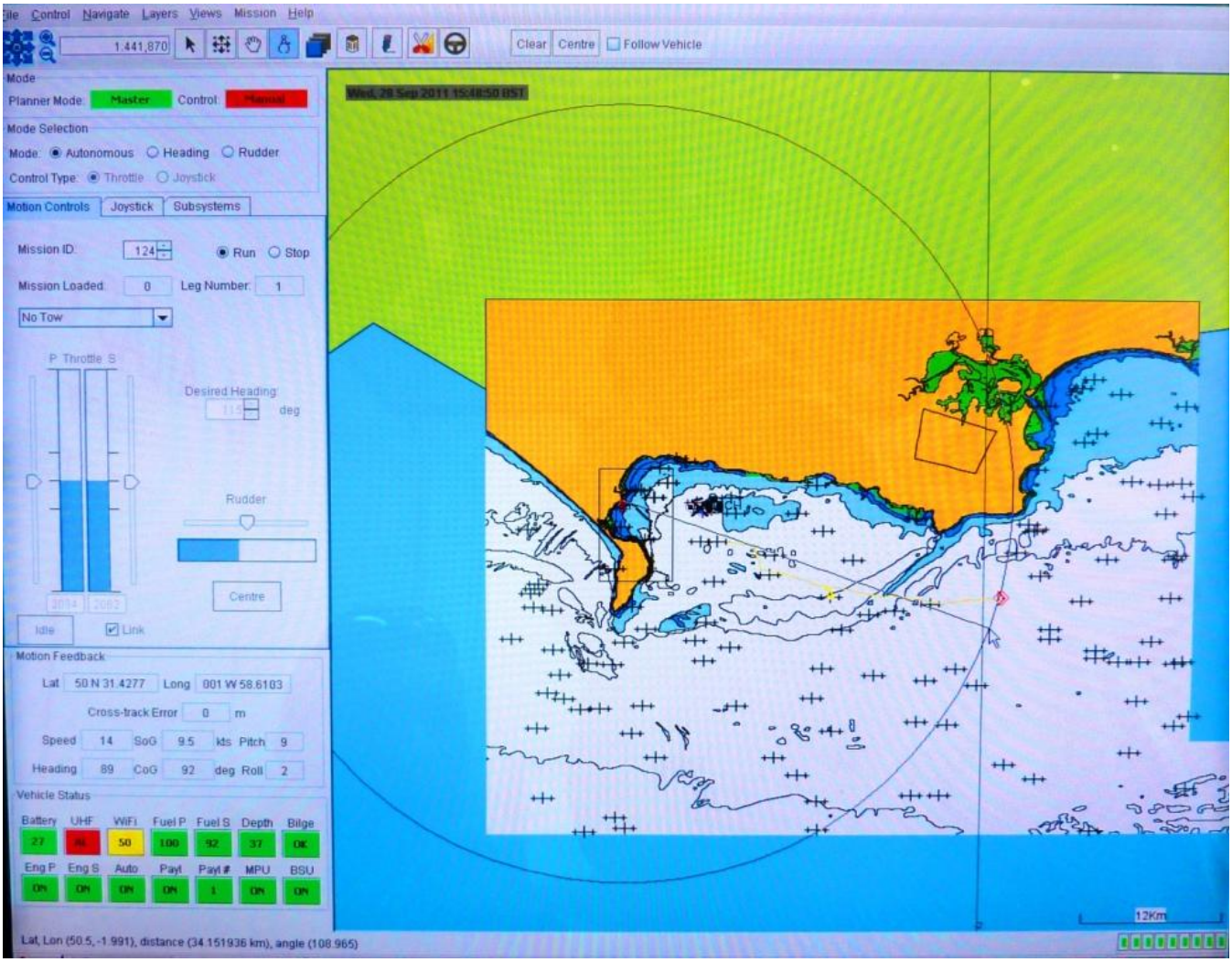
2010 Rajant Corporation in collaboration with Allsopp Helikites Ltd, Hampshire, England. Created an airborne Mobile Ad-Hoc Network using a 1Kg/200mW Rajant MANET "Breadcrumb" lifted on a small 9ft long Desert Star Helikite flying at 500ft. It operated a PTZ camera and relayed full streaming video 6 miles.

2010-Ongoing. Norwegian Government Sponsored Research. Radio-Relay to Unmanned Surface Vehicles using sea-borne Helikites. Helikites operated successfully from ships and RIB's in within the arctic circle, winter and summer. Furthest successful sea-deployed Helikite radio relay is presently 55NM over a 2000ft mountain range. This used a 15m3 Desert Star Helikite in summer 2012.

Picture 1. 10m3 Desert Star Helikite in Arctic Ocean

Picture 2. Helikite being towed by USV in high winds.

2011 Atlas Elektronic Radio-relay over-the-horizon to "FAST" manned/unmanned trials boat. Clear 2Mb radio relay achieved out to 30Km from Portland to the 'FAST' boat via an 11m3 Skyhook Helikite flying at 600ft.



Picture 3. Screen-Shot showing FAST vessel 34Km from Portland with all comms routed via a Skyhook Helikite flying at 600ft over Portland Harbour.

2012 April/May/June. Extensive US Army Trials of two 64m3 Desert Star Helikites lifting Cloud-Cap Tase 400 cameras. The Helikites comprehensively defeated all other competing types of tethered aerostats in these extensive desert trials. At one point a Helikite flew unscathed through a "dust-devil" mini tornado and then filmed from its airborne gyro-camera the subsequent total destruction of a competing "blimp" shaped aerostat by the same dust-devil, watched by the government inspector. From the trial the US Army ordered numerous 75m3 Desert Star Helikites to carry Cloud-Cap Tase 400 cameras for use in Afghanistan.

2012 - Ongoing. Australian Defence Force Radio-Relay Helikites

A number of 18m3 Desert Star Helikites plus electric winches and Helibases were supplied to lift Raytheon 'Microlight' 5W MANET radios. These radios provide both high data-rate comms and also exact positioning independent of GPS. During extensive trials over many months the Helikites reliably lifted the radios persistently to 800ft providing over-the-horizon comms out to 42 miles (5,542 Sq miles). Later larger 45m3 Desert Star Helikites were procured which also underwent months of trials before being put into service with the Australian Special Forces. These small $30,000 Helikite systems, transported in 5 Pelicases (including helium cylinders) replaced two 800 m3 TCOM 17M aerostats costing $1,500,000 each that proved far too large to be practical.

Australian Special Forces 45m3 Desert Star Helikite lifting COMMS equipment

2012 June/July. 64m3 Desert Star Helikite on deployment on a US Navy ship lifting electronic equipment + fibre-optic cable to 5000ft above the sea. Allsopp Helikites Ltd supplied all ground handling equipment such as Large Helikite Winch and Helibase. No significant problems were encountered. In fact operating from a ship was sometimes even easier than operation from land.

Pictures 4 & 5 Simple, easy and safe deployment of a 64m3 Desert Star Helikite up to 5000ft from a small US naval vessel on operations.

Picture 6. View from Helikite at 5000ft. The naval vessel is the small white shape in the centre of the picture.

Picture 7. Helikite flying at high altitude behind US Naval vessel. The Helikite is the small grey dot in the sky.

2013 - Ongoing. European Commission 'ABSOLUTE' Emergency 4G Communications Project
This is a large project funded by the EU. Its aim is to create an instant, airborne 4G base station for national emergencies and temporary events. It will be able to communicate simultaneously with thousands of first responders and victims via their mobile phones. After extensive research of all possible airborne platforms the scientists recognised the 34m3 Desert Star Helikite to be the most suitable air vehicle. This will be flown from the ground or from a small dedicated trailer. The project is on target and it is expected that a fully working system providing 300Mb per Helikite, will be available by the end of 2015.

34m3 Desert Star Helikite plus trailer and winch. For EU ABSOLUTE Emergency 4G Communications Project.
This stand-alone launch system can be easily operated from land, boats or ships.

2015 - Ongoing Ukraine.

The government forces are woefully short of most types of COMMS. Recently were were asked to supply to them a 34m3 Defender Helikite + small 12 volt winch + Helibase and 1,500ft of flying line to lift a Motorola 4400 radio. This was funded by charitable subscription as there is no government money available. They received the Helikite in Ukraine via courier within one day of despatch. The next day they took about an hour to set up, inflate and fly the Helikite without any training, just a booklet of instructions. They immediately got 60 miles COMMS range using the Helikite, instead of the usual couple of miles ground to ground. So the Helikite gave radio coverage 11,311 square miles.

34m3 Defender Helikite lifting Motorola 4400 radio, and on Helibase, in Ukraine

8) CONCLUSION

High-altitude, all-weather Helikites lifting MANET radios or 4G relays create an extensive area in which there is full broadband radio communications for personnel, ships, sensors and unmanned vehicles - limited only by the numbers of Helikites and radios available.

Helikites have proven they can provide a simple, reliable way of greatly increasing military radio-range and bandwidth at very little cost. No extra ships, masts, vehicles, aircraft or inter-service co-operation is required. Helikites are significant force multipliers that can immediately increase reduce exposure to risk for personnel so reducing casualties.

Ultimately the Helikites' greatest virtue is its ability to allow network-centric war-fighters far removed from the battlefield, to directly help their colleagues at sea via the remote operation of unmanned vehicles, mines, munitions and sensors.

Helikites plus MANET radios and 4G, allow a vast previously untapped, worldwide network, of thousands of human and computer resources, to be concentrated into the centre of the naval 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