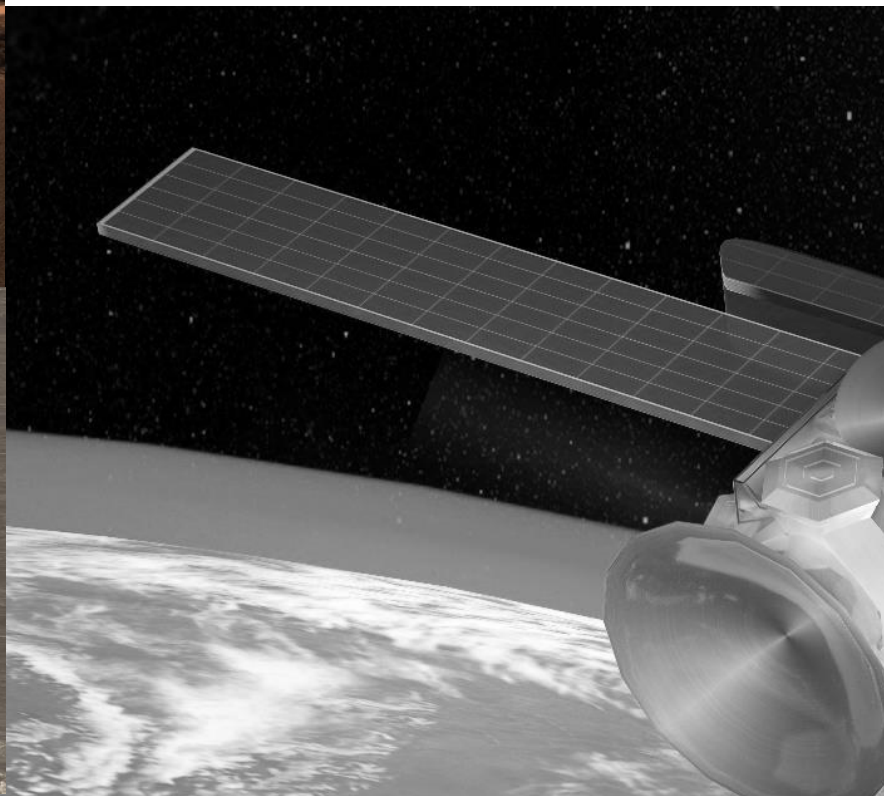
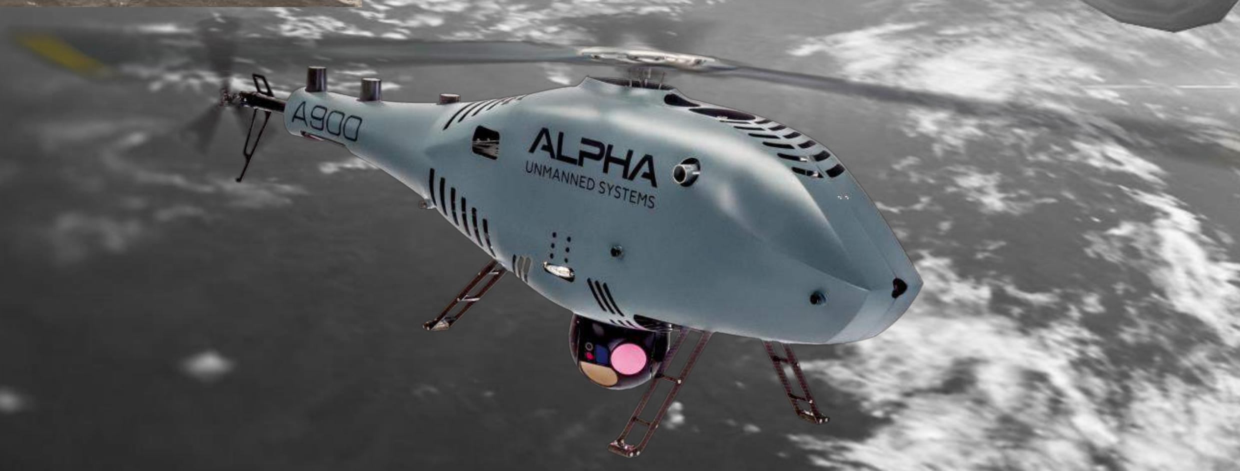
ALPHA
UNMANNED SYSTEMS



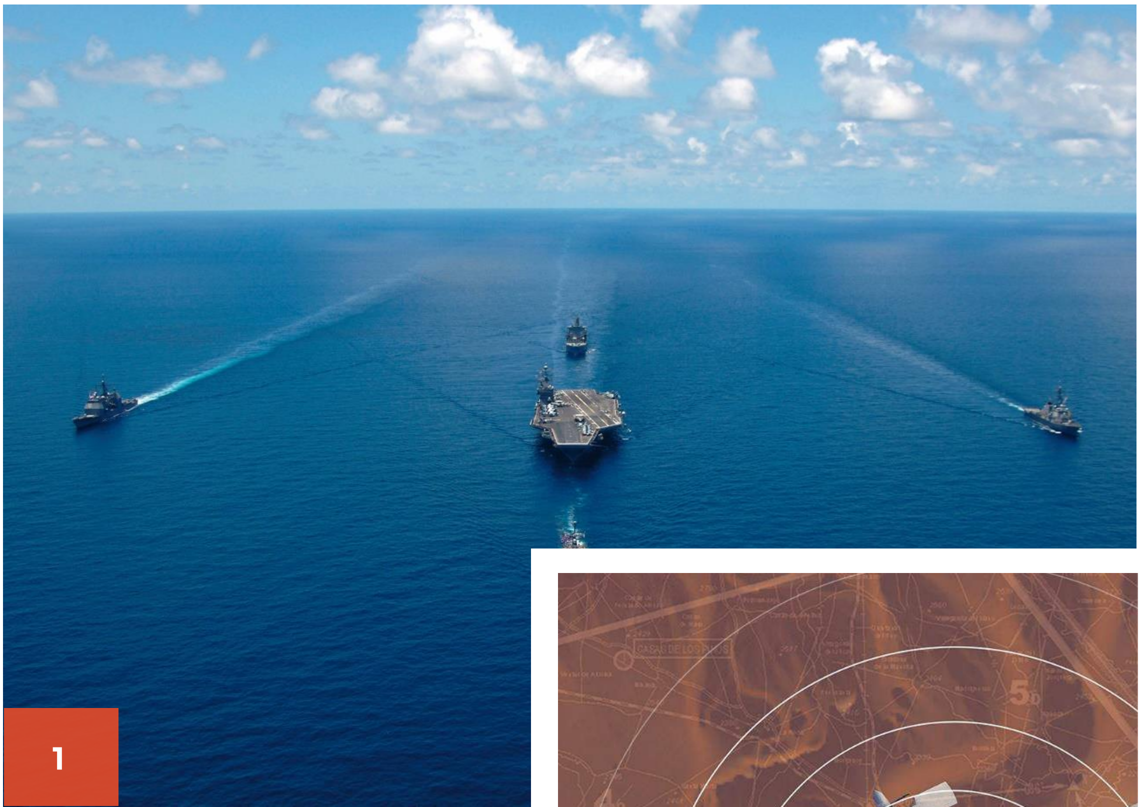


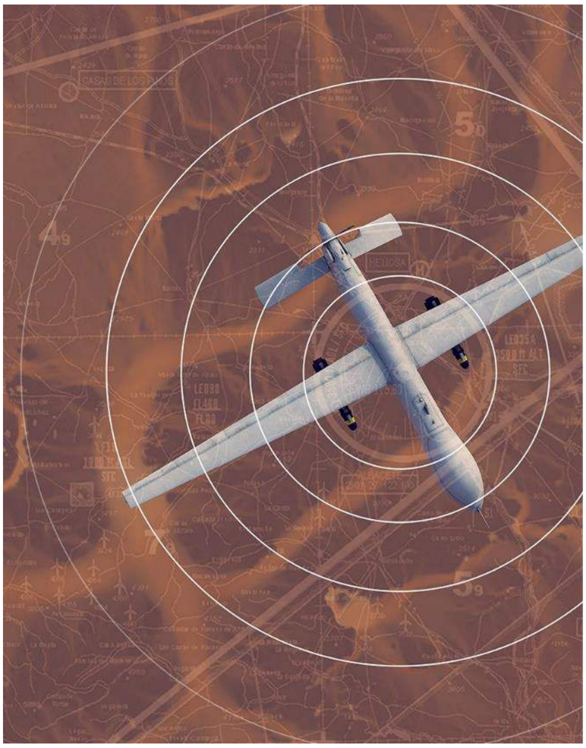
CHALLENGES & SOLUTIONS

NAVIGATION IN GNSS-DENIED ENVIRONMENTS FOR SMALL UNMANNED HELICOPTERS

INTRODUCTION

Drones continue to demonstrate their effectiveness on the battlefield; the types available include very small commercial drones used for close range surveillance and cardboard disposable drones with incredible range and operational capabilities. However despite its huge potential, drone technology has an Achilles heel that is rarely mentioned: it is dependent on Global Navigation Satellite System (GNSS) navigation.





All drones rely on GNSS to maintain a stable position and/or to navigate between waypoints. Even the target geolocation features of cameras are based on GNSS positioning and are unable to work properly without an external position feed. At the same time, all small drones use Micro-electromechanical Systems (MEMS) sensors to estimate their attitude. These sensors include accelerometers, gyroscopes and magnetometers that provide data on the aircraft's three axes.

A common assumption is that by having accelerometers and gyroscopes, a simple integration of their data can provide speed and orientation; and that with a second integration, position can also be calculated.

THE MEASUREMENTS THAT THESE SENSORS PROVIDE INCLUDE ERRORS, NOISE AND DEVIATION

However, it is actually not that easy. The measurements that these sensors provide include errors, noise and deviation. Also, whilst the sensors may include relatively small errors in their raw measurements, when integrated together they generate much bigger errors that make navigation and position estimation difficult.

When the GNSS signal is lost, the safest strategy for a drone is often to hover or loiter around a point, maintaining attitude by means of the barometric pressure and altitude reading from the Attitude and Heading Reference System (AHRS), in other words keeping pitch and roll angles at 0. With this strategy the Unmanned Aerial Vehicle (UAV) will drift from its position proportional to wind speed and direction.

DRONE STRATEGY
Hover or loiter around a point maintaining attitude

UAV STRATEGY
Drift from its position proportional to wind speed and direction

In case of total GNSS loss, the external human pilot must take manual control if the UAV is to be safely landed.

ALPHA
UNMANNED SYSTEMS

BUT WHAT HAPPENS WHEN THE UAV IS JAMMED?

Commercial jammers and counter-UAV systems function by directing strong electromagnetic energy towards the aircraft using the most commonly used frequencies for UAVs, which for communications are 900 MHz, 2.4 GHz or 5.8 GHz, and for GNSS are the L1 and L2 bands. The effect of the strong signals emitted by jammers is that the Signal-to-Noise Ratio (SNR) is so small that the receiver cannot decode the real signal from the noise; this is analogous to when we cannot understand someone speaking in a room full of other people talking.

When it is jammed, the UAV will lose both GNSS, and therefore navigation, and remote control from the pilot. Again, the most conservative option for the autopilot is to maintain a constant attitude (pitch and roll equal to 0) and to descend in controlled way until the UAV touches the ground. This is what the vast majority of commercially available drones do and what makes jammers and other counter-UAV measures so effective.

Unlike these commercial systems, many military fixed wing UAVs use more advanced autopilots which incorporate a calibrated Air Data System (ADS) which includes a pitot tube and static port; these systems are able to calculate the estimated wind, which in the case of a loss of GNSS signal can be used to estimate the UAV's ground speed by means of the following formula: Estimated Ground Speed = Indicated Air Speed - Estimated Wind.

By means of the integration of air speed and assuming that wind direction and speed is constant, we can estimate the UAV position with approximate precision that is usually 'good enough'.

BUT WHAT DOES 'GOOD ENOUGH' MEAN?

It means that the UAV can maintain and follow a flight plan and also can be commanded to fly to a certain area, or to return home safely if the UAV is Beyond Line Of Sight (BLOS). The long-term error with current systems is around 50 meters per minute, although the more unstable the wind, the higher the error will be.

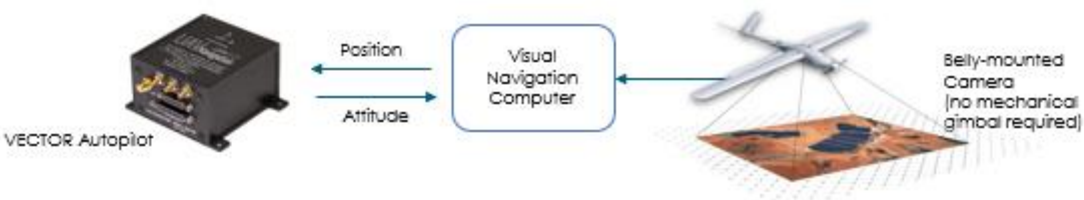
Normally multirotor drones do not have an ADS so when jammed the drone is lost. However, Alpha's helicopter UAVs have an integrated, complete high-end ADS and wind estimator.

Due to the fact that a UAV's navigation can be enhanced via Inertial Navigation Systems (INS) and ADS-aided navigation, its position can be estimated even though error will be accumulated over time. Over longer periods this accumulated error will begin to have an adverse effect on operational aspects of the mission, such as: the true position of the aircraft, the aiming of the tracking antenna which might lead to a potential loss of communications or range reduction, inaccurate or unreliable target coordinate estimation, or even the potential loss of the aircraft.

Thanks to the cutting-edge autopilot technology used by Alpha, there is now the possibility of integrating an onboard Visual Navigation System (VNS) that eliminates any accumulated positional long term error and provides real navigation capabilities in jammed environments.

THIS MEANS THAT ALPHA'S HELICOPTERS ARE ABLE TO ACHIEVE GNSS-DENIED NAVIGATION.

The VNS is a device that features a downlooking camera coupled with a powerfull video processing unit that is in direct comunication with the autopilot. The VNS acts as another sensor input, receiving IMU data from the autopilot and providing positional data in a similar way to a GNSS system.



This technology has two modes of operation, depending on the availability of a previously generated georeferenced map:

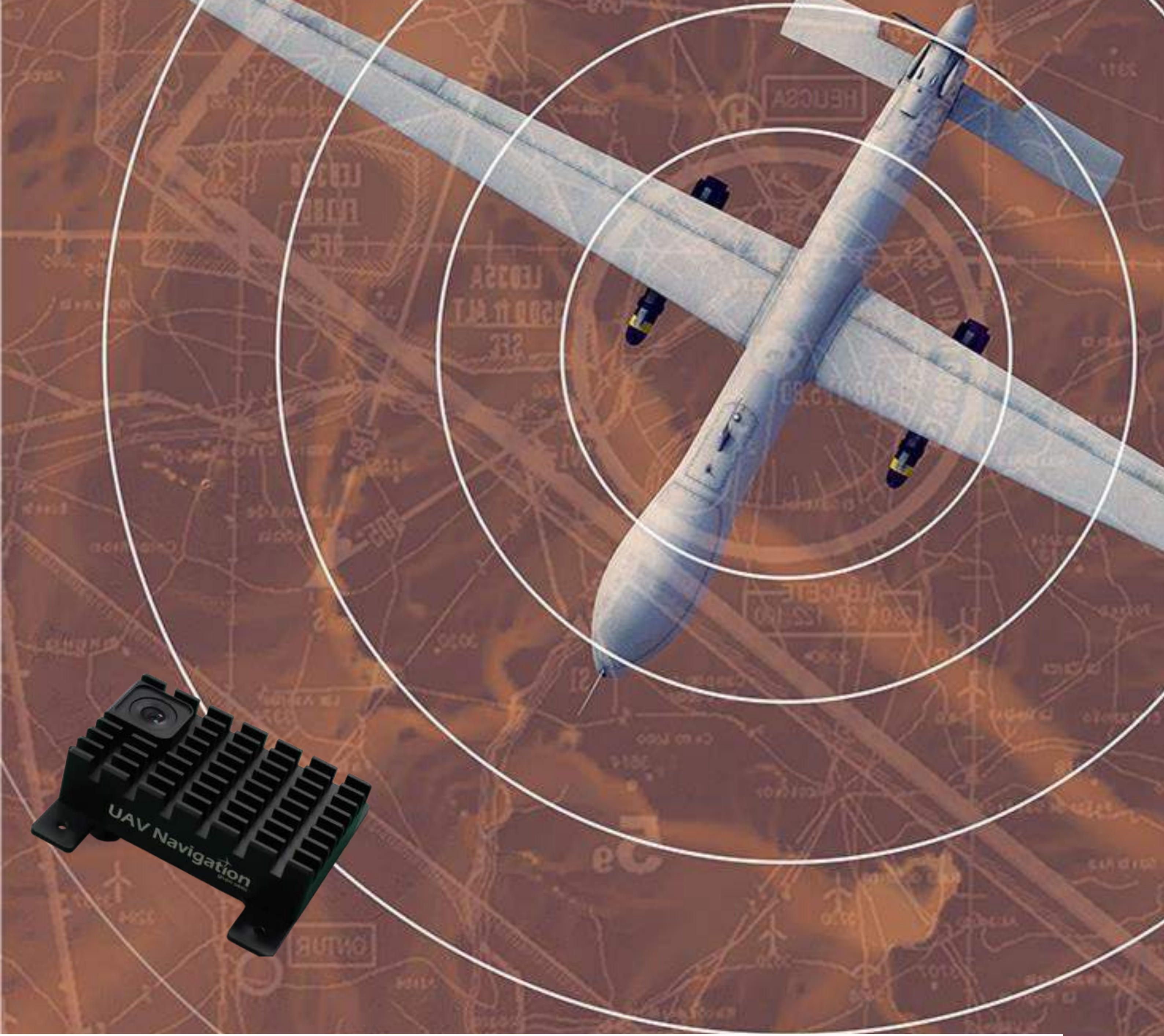
OVERFLOWN PREVIOUSLY	NOT OVERFLOWN PREVIOUSLY
If the area has been overflown previously with GNSS and VNS active, the system will have generated a map of georeferenced images which the VNS can use to locate the UAV with extreme accuracy.	If the area has not been overflown (i.e. no images recorded), the VNS can still improve INS navigation and position estimation by using the camera to identify the movement of points on the ground as the UAV flies forward. This again drastically reduces long term error.

Taking advantage of this capability, the operator can therefore fly the VNS-equipped UAV towards an area that has previously not been overflown, generating VNS data (images) to 'map out' the area. If jamming of the GNSS system is subsequently experienced, then the mission can be continued safe in the knowledge that they can command the UAV to fly towards a 'mapped out' area in order to restore positional accuracy or to recover the UAV home.

If the entire area has been overflown previously then a complete operation can be executed without the GNSS system.

Another possibility is to set the datalink/radio to silent mode (i.e. not transmitting) when overflying an area of interest in order to record VNS imagery on a pre-programmed flight. This means that the enemy will not be alerted to the UAV's presence due to RF radio transmission.

The VNS technology incorporated into Alpha's A-800 and A-900 helicopter UAVs is a game changer, meaning that small drones can now be used on the battlefield without relying on GNSS systems.



P: +1 (0) 123 000 564
E: info@alphaunmannedsystems.com
w: www.alphaunmannedsystems.com

Avda. Fuente Nueva, 14 nave 16A
San Sebastián de los Reyes (Madrid) - Spain

ALPHA®
UNMANNED SYSTEMS