

THE SURVEY ASSOCIATION

CLIENT GUIDE TO **SMALL UNMANNED AIRCRAFT SURVEYS**

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The Survey Association's Client Guides are primarily aimed at other professionals such as engineers, architects, planners and clients in general. They are not intended to go 'in depth' into practical issues but to act as a basic guide on a type of survey and in particular, on procedures and regulations which may govern how a certain aspect of the survey is carried out.

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1. What is a Small Unmanned Aircraft (SUA) Survey?

There are many different names and acronyms used to refer to small unmanned aircraft, 'drone' being the one most commonly used by the media. Commercial operators do not favour this term due to its negative connotations. Preferred names include, flying camera, Remotely Piloted Aircraft (RPA), Unmanned Aerial Vehicle (UAV), Unmanned Aerial System (UAS), Unmanned Aircraft (UA) and Small Unmanned Aircraft (SUA). The term SUA will be used throughout this document.

A SUA comes in two principal designs: rotary wing and fixed wing. The rotary wing SUA can look like a twin-bladed model helicopter or come with 4, 6, 8 or even 12 smaller sets of rotor blades. Rotary wing SUAs are generally used for inspection, monitoring and presentational work (especially on structures) due to their manoeuvrability, hover function and their capacity to operate in confined spaces. They can be used for survey and mapping purposes but their slower speed of flight, coupled with shorter battery life, makes them currently less suitable for this type of application. A fixed wing aircraft (as per Figure 1) is the type of SUA that is typically used for survey work over large areas up to 1km^2. Like a normal aircraft, its shape gives good stability so it can glide over a site allowing photographs to be taken efficiently, in a linear order.

Other SUA designs, such as kites and balloons, have been successfully used for survey projects in the past but for the purpose of this guide we shall concentrate on the rotary and fixed wing designs.



Figure 1:
Example of a fixed wing SUA

SUAs, used in combination with photogrammetry, are an emerging technology, providing an innovative platform for low-level aerial imagery acquisition. Easy to mobilise and flexible in operation, SUAs provide users with the ability to create Digital Surface Models (DSM) and orthophotos from aerial imagery, for mid-sized areas previously only accessible at higher costs and with longer planning cycles. SUAs are used in a variety of applications, including preliminary surveys for corridors and rights-of-way, volumetric surveys, high-level topographic surveys, landfill inspection and much more.





Figure 2 – left:
The SUA takes hundreds of overlapping images

Figure 3 – right:
The SUA flight plan is configured to suit individual areas on site

2. How does it work?

In the case of the fixed-wing SUA, the typical system consists of an airframe containing integrated GNSS (Global Navigation Satellite Systems), inertial system, battery, radio and a minimum 10 megapixel digital camera. A portable computer (known as the Ground Control Station or GCS) is used to operate the SUA and by pre-defining the area of interest on the GCS, the SUA can use its on-board navigation system to fly automatically from launch to landing. The terrain can then be photogrammetrically mapped through capturing parallel strips of consecutive camera shots that overlap in both forward and side directions (Figure 2). The flight plan can be adjusted on site to suit the full extent of the location, which may differ from the mapping available in desk-based studies (Figure 3). SUAs can also be flown manually for image collection if necessary. The photos are normally stored on board the SUA's camera and log files, relating to position and height, generated by on-board GNSS observations, are transferred back to the tablet computer via radio communication in real-time (Figure 4).

Most sites will require multiple flights, particularly where large sites are to be surveyed. Battery changes will be required at varying intervals depending on the system being used and the weather conditions. After each landing the photographs can be quickly reviewed on site to ensure that all areas have been captured during each flight (Figure 5).

Once the flight is complete, the 'raw' images are retrieved from the camera and processed in specialist photogrammetric-based software which delivers the DSM and geo-referenced orthophotos. There are a wide range of providers and configuration of equipment available and you should expect to cover an area of approximately 1km^2 during one flying sortie. With forward planning and spare batteries, multiple flights can be carried out in a day.

3. What is the workflow for the image processing?

When using an SUA there are three main steps to the image processing: pre-processing, registration and DSM generation.

In the pre-processing phase, any poor quality or redundant images are removed. In a parallel step, raw images are processed to remove distortion using a camera calibration profile. This profile is generated by calibrating the camera on a regular basis, which in itself is an image processing step that can be fully automated. Although post-processing can be undertaken without calibration it will lead to a reduced accuracy of 3D data due to the fact that the compact cameras typically installed on the SUA have small lenses that are prone to distortion.

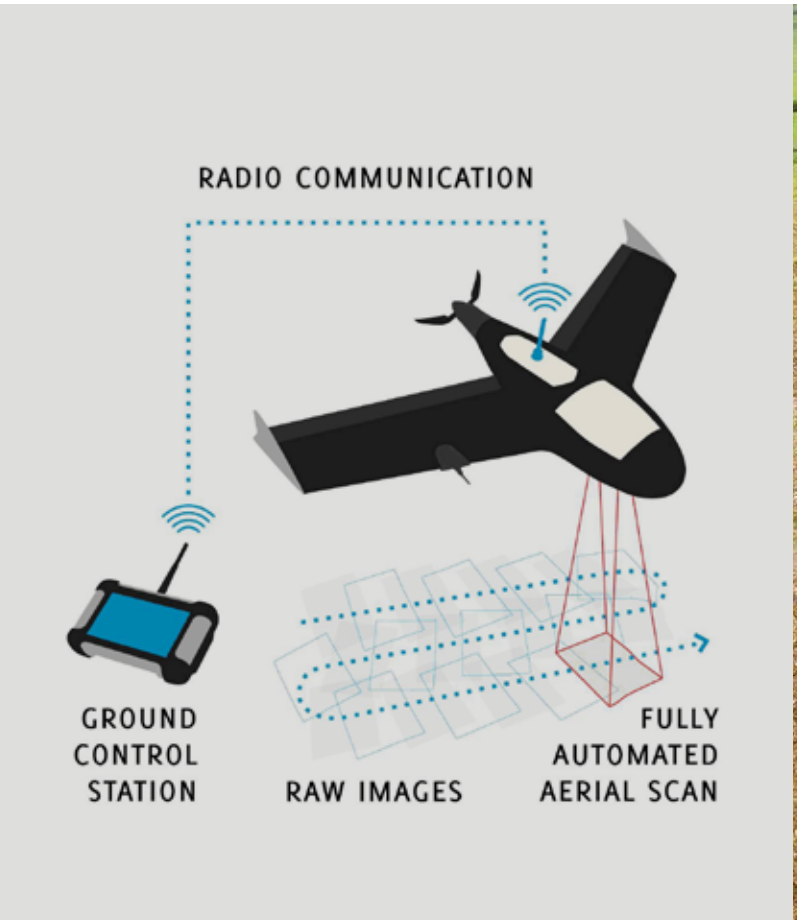



Figure 4 – left:
The interface between the tablet computer (GCS) and SUA

Figure 5 – right:
When each flight is completed photographs can be reviewed on site

In the registration phase image position and orientation data is generated in a user-specified coordinate system. This data, including the undistorted images, constitute the core information needed to create the DSM and derived products, such as the orthophotos.

In the DSM generation phase, the data created from the previous two phases can be used to create a triangular network of 3D points across the surveyed area. This is generated using photogrammetric based software that analyses the multiple overlap areas across adjacent image sets. As well as determining the position of the camera as it was 'in flight', individual 3D points can then be generated by automatically correlating similar pixels that appear across each image. Once created, the 3D points can then be interconnected to form a mesh of the surface at differing resolutions.

4. What are the operational regulations?

To operate a SUA commercially in the United Kingdom (UK), the company and SUA operators must hold a Civil Aviation Authority (CAA) 'Permission to Operate' licence. In order for this to be granted the company must submit a SUA operations manual and a SUA technical manual to the CAA.

Commercial SUA operators (pilots) in the UK must also sit a CAA ground school course and exam followed by a flight test on the SUA they are to operate. Once these exams are passed the operator is awarded a Certification of Competence on a specific SUA type.

The final hurdle is aviation insurance. Premiums vary and more insurers are moving into the market as the technology advances. Some factors that affect insurance premiums are:

- Experience of the company as a SUA commercial operator
- Experience of SUA operators (hours and types flown)
- Hours to be flown per year
- Type of environment the system is to be flown in.

Regulations for the use of SUAs in the UK are changing; keep up to date by checking the CAA UK on www.caa.co.uk/uas and www.caa.co.uk/cap393

5. What are the limitations of SUAs in surveying?

Current regulations allow for small SUAs to be employed as a commercial tool in UK airspace. Given the weight limitations imposed by the CAA, heavy surveying equipment such as LiDAR cannot currently be carried, therefore photogrammetry, in its multi-image/ Structure-from-Motion form, is used instead. The data outputs are currently limited to orthophoto mosaics and DSMs, in both point and meshed forms.

Operational limitations include:

- No operations over highly urbanised areas
- Ground measurements are limited by dense vegetation and tree cover
- Limited to 500 metre line of sight operation – when using a fixed wing SUA this limits the survey area per flight to 1km^2 (although you can fly bigger areas with detect and avoid plans)
- Limited to 122m/400ft flying height
- Weather – principally wind speed although it depends on the type of SUA used
- Poor quality camera images can be detrimental to the final results.

6. What level of accuracy can be achieved?

Accuracy can be the most important factor to an engineering professional using a survey model or drawing. Whatever the reason for the survey, in most cases, professionals will be making decisions based on the results. Whether the tolerance of the project is millimetres or metres, it is important the client communicates this to the surveyor. The surveyor using the SUA will be able to plan the survey to produce the results closest to the project requirements, or may say that the SUA survey option is not suitable for the accuracy required. In all cases the surveyor should deliver a report, together with the SUA survey data, that describes the methods used. The report should also contain a good sample of ground proofing checks, emanating from other survey techniques to give the client confidence in the dataset. This is the only real way that the accuracy of the SUA survey can be assessed, as the survey platform and instrumentation can perform variably given differing factors including, weather, flight planning, GNSS ambiguities, operator, survey control, processing techniques, altitude and point filtering.

As a rule of thumb the precision, (or relative accuracy) of the SUA survey after processing, is known to be within the order of 1-2 pixels in plan and 2-3 pixels in height. The absolute accuracy of a SUA survey will depend on the georeferencing that is derived from the GNSS and/or Ground Control Points (GCP). As SUAs are not equipped with geodetic GNSS, if GCPs are not taken into consideration the accuracy of the results may suffer a global shift of up to 20 metres, depending on atmospheric conditions and satellite geometry. By using geodetic GNSS and a suitable number of GCPs in the processing, the accuracy of the survey can be derived from the average Ground Sampling Distance (GSD) (the distance on the ground between pixel centres measured on the photograph). Using this principle, if the GSD of a survey is 40mm the accuracy could be assumed to be approximately 40-80mm in plan and 80-120mm in height.

7. What are the dangers in using SUAs?

A SUA is an airborne projectile with mass that can fail and descend rapidly to the ground. With this in mind, the CAA UK have imposed restrictions on where flights can take place and under what circumstances a flight can be made. The CAA UK have categorised SUAs by weight to create strict boundaries as to who can fly them and where – the heavier class SUAs need more experienced operators and come under a different set of regulations – this is clearly because they are more dangerous. If instructing a commercial SUA survey it is pertinent to make thorough checks that the operator complies with CAA UK regulations and has provided a full risk assessment and method statement of the planned flight. This will ensure that the operator is working within the CAA law and thus providing a service which will minimise the risk of a serious accident.

8. What are the advantages of SUAs in surveying?

The principle advantage in using any SUA is its ability to provide a remotely controlled platform for acquiring low-level aerial imagery, often from unique vantage points. Like most surveying equipment, a SUA can be carried in the back of a car or taken as luggage on an aircraft. A SUA adds value in its ability to cover large areas quickly and operate when manned aerial surveys cannot be flown or it is difficult or dangerous to do a ground survey. Sometimes the imagery of an area of interest is too outdated or simply non-existent and satellite imagery is not always available when you need it and often lacks the required resolution. Here is a list of some of the advantages that a SUA survey can offer:

- Survey difficult to reach, sensitive or dangerous areas e.g. survey a mine without interruption of mining operations
- Fly at lower altitudes and below some weather conditions not possible with manned aircraft
- High resolution mapping – in ideal conditions it is possible to get down to 3cm ground sampling distance (GSD)
- Cover up to 1.0km^2 per flight
- High wind and weather operations (up to 65km/hr winds for fixed-wing and up to 20km/hr for rotary winged SUAs)
- On certain sites cost and time savings can be made over manned aircraft photogrammetry
- Fast and flexible – the logistics and operational requirements for a SUA are minimal. This allows for flexible operations anywhere in the world (dependent on local legislation)
- Battery powered – almost no maintenance required but with the capability to power flight times of up to 45 minutes for some fixed wing SUAs
- Fast turnaround of data.

9. Uses of photogrammetric data

There are many uses for photogrammetric data, but generally any application that requires a volumetric or three-dimensional set of data or topographic vector information can be considered.

Typical applications include:

- Topographic surveying
- Infrastructure modeling
- Asset inventory
- 2D and 3D vector mapping
- Visualisation/animation
- Volumetric analysis
- Forest monitoring
- Flood plain surveys
- Vegetation surveys
- Survey reconnaissance
- Environmental monitoring
- Site change detection.

10. Survey specification

It is important that the client specifies their requirements in detail and should include the following information when requesting a quotation:

1. The area to be surveyed.
2. The level of detail required.
3. The accuracy required.
4. The grid and datum to which the survey is to be related.
5. Access restrictions.
6. Flying restrictions.
7. How the data is to be presented.

11. Case study

Figure 6 is a DSM of an open mine generated from low-level aerial images captured from a SUA. The photogrammetric data from this was used for volumetric calculations as well as measuring the width of tracks and terracing.

A further example is the following DSM of a quarry, formed by photogrammetry captured from a SUA (Figure 7). The data from this was used in volumetric calculations and for planning extension submissions.

When the terrain to be measured is rather large – typically tens of hectares to many square kilometres – a SUA is more efficient than ground survey work, which can take many days or weeks to complete. A SUA survey also allows for the creation of very dense point clouds – similar in density to a typical aerial LiDAR scanner – but with the advantage of requiring less demanding and costly equipment.

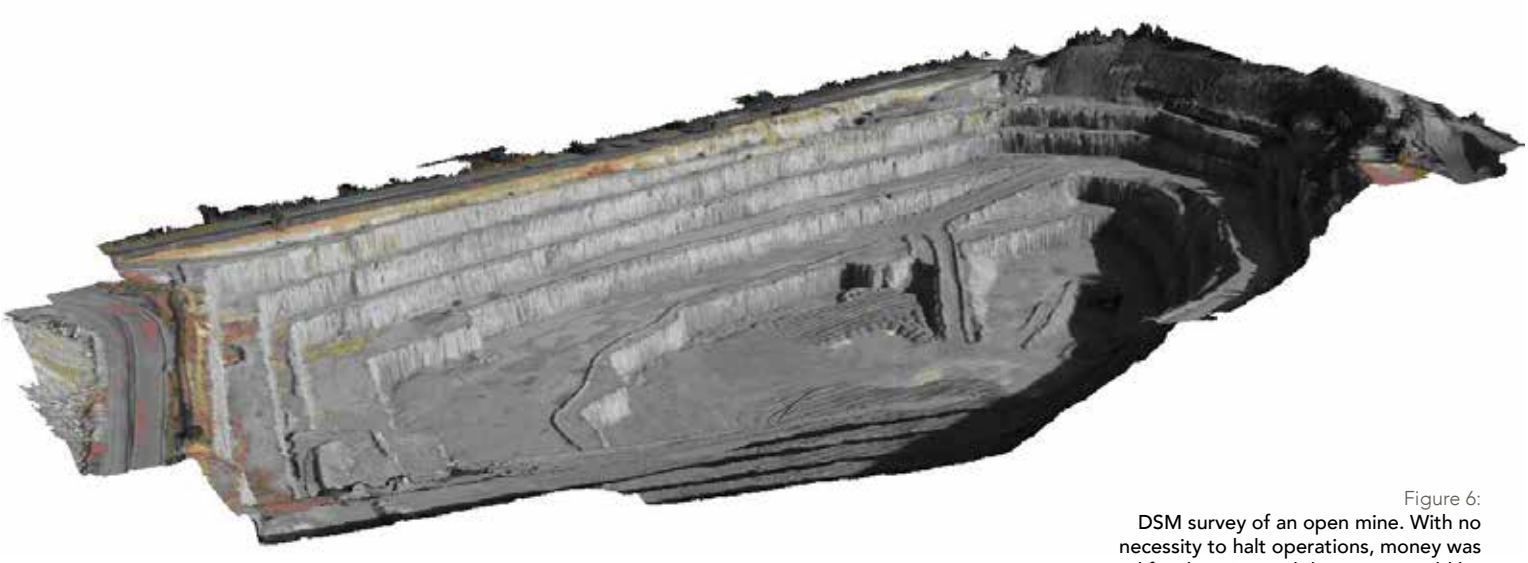

Figure 6:
DSM survey of an open mine. With no necessity to halt operations, money was saved for the mine and the survey could be carried out from a position of safety.



Figure 7:
DSM taken of a working quarry

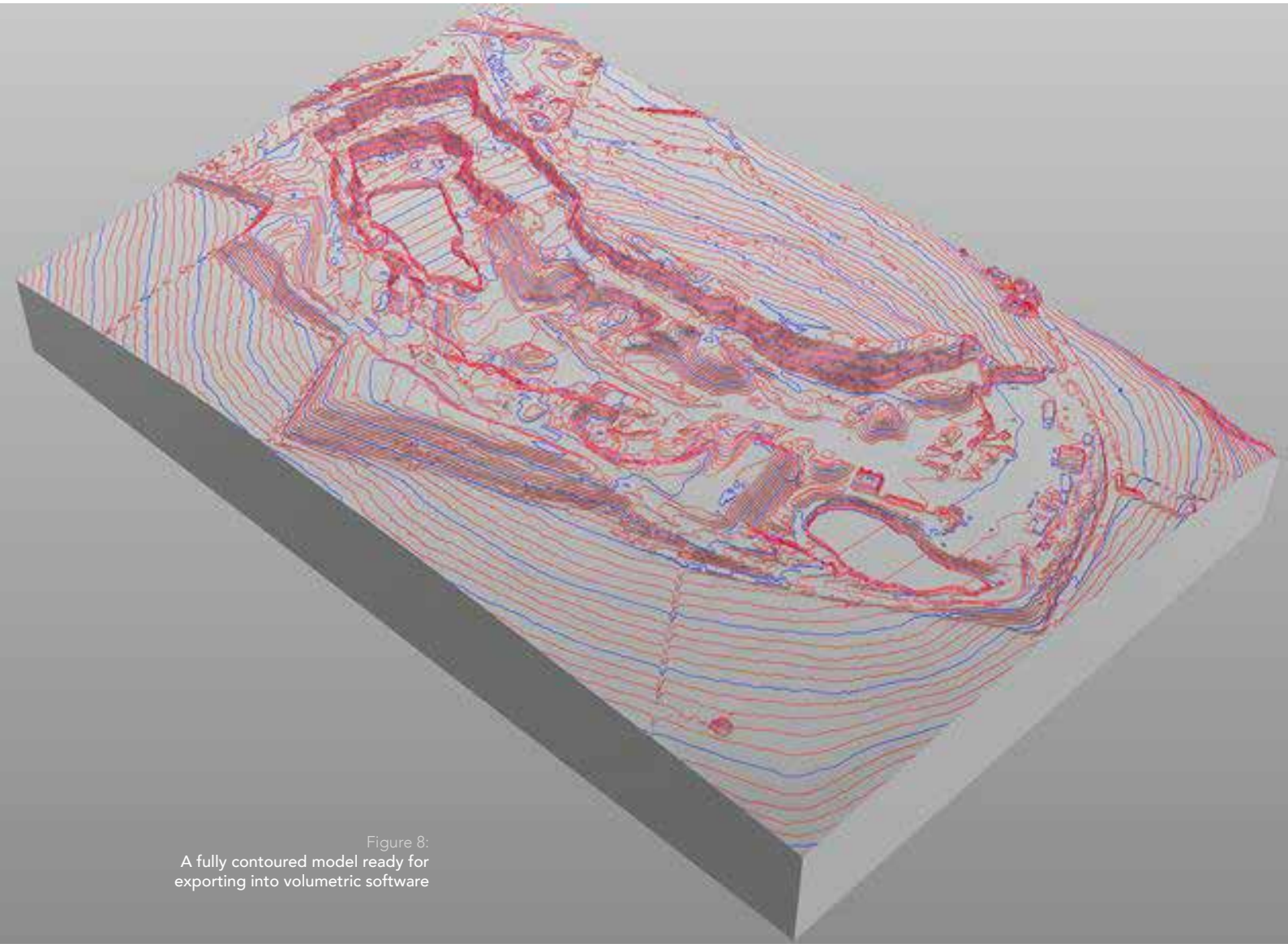

Figure 8:
A fully contoured model ready for exporting into volumetric software

To capture the level of detail in the mine pictured above by traditional survey methods would have taken considerably longer and therefore a SUA survey has provided an optimum solution in terms of detail and cost. A fully contoured model (Figure 8) can be produced from the SUA survey data which can then be exported into typical proprietary software for volumetric calculations e.g. LSS, LisCAD, NRG, Carlson.

12. Summary

SUA surveys are a cost effective alternative to more traditional surveys, given certain criteria. They open up the feasibility of surveying some projects by their ability to cover large areas of terrain in a short period of time using relatively low cost equipment. If being undertaken on a commercial basis it is important to use a fully qualified, insured operator with experience in data capture by this method. Another important factor is the required accuracy of the survey results. Accuracy should be established before commencement of the survey and checked by sampling areas using more traditional survey methods with the results being published in the report.

SUA surveys have become a recognised surveying technique which is constantly developing as technology and the law regarding air space changes. If you are considering commissioning a survey of this nature then please get in touch with a TSA member company with expertise in this field. They will update you on what is possible at the time of asking.

13. Glossary of terms

TERM	EXPLANATION
Airframe	The structure of the aircraft exclusive of its power source
CAA	Civil Aviation Authority
DSM	A Digital Surface Model represents the earth's surface and includes all objects on it such as buildings, vegetation etc
DTM	A Digital Terrain Model represents the bare earth's surface with all objects, such as buildings, vegetation etc, digitally removed
GCS	Ground Control Station
GNSS	Global Navigation Satellite Systems
GSD	Ground Sampling Distance
Inertial System	A frame of reference within which bodies are not accelerated unless acted upon by external forces
IMU	Inertial Measurement Unit
INS	Inertial Navigational System – combines information from GNSS receivers and an IMU to generate highly accurate positional and orientation estimates for the trajectory of the system
Orthophoto	An orthophotograph, or orthophoto, is a photograph that has been geometrically corrected ("orthorectified") for any errors arising out of tilts of the camera, relative to the surface relief, such that the scale across the image is uniform hence displays the same lack of distortion as a map
RPA	Remotely Piloted Aircraft
SfM	Structure from Motion – a computer vision technique that allows a three-dimensional representation of a surface to be photogrammetrically derived from movement across it
SUA	Small Unmanned Aircraft (preferred terminology)
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicle

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References:

CAP 722: Unmanned Aircraft System Operations in UK Airspace – Guidance available for free download at:
www.caa.co.uk/application.aspx?catid=33&pagetype=65&appid=11&mode=detail&id=415

The Survey Association

Formed in 1979 as The UK Land and Hydrographic Association, TSA is now established as the representative organisation for UK private surveying firms. The Association's aims are:

> To provide a vehicle for members to act effectively together on agreed courses of action.

> To promote the interests of the profession to all those who determine the economic and social conditions in which the industry operates.

> To identify and represent the views of the industry.

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By using a TSA member you can be assured that your project will get off to the best possible start. Whatever the size of project, you can be certain that TSA member companies are expert in the provision and management of spatially related data on which to base your concept, design and construction.

Professional attention from a TSA surveyor will reduce risk, repetition, possibly save you money and will ensure that your project receives the best possible attention.

TSA Contact Details

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