



CONSTRUCTION
INDUSTRY COUNCIL
建造業議會



Reference Materials - Sample Specification for Provision of Image Capturing and Surveying Services by Unmanned Aircraft Systems

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PREFACE

The Construction Industry Council (CIC) is committed to seeking continuous improvement in all aspects of the construction industry in Hong Kong. To achieve this aim, the CIC forms Committees, Task Forces and other forums to review specific areas of work with the intention of producing Alerts, Reference Materials, Guidelines and Codes of Conduct to assist participants in the industry to strive for excellence.

The CIC appreciates that some improvements and practices can be implemented immediately whilst others may take more time for implementation. It is for this reason that four separate categories of publication have been adopted, the purposes of which are as follows:

Alerts	The Alerts are reminders in form of brief leaflets produced quickly to draw the immediate attention of relevant stakeholders to the need to follow some good practices or to implement some preventive measures in relation to the construction industry.
Reference Materials	The Reference Materials are standards or methodologies generally adopted and regarded by the industry as good practices. The CIC recommends the adoption of the Reference Materials by industry stakeholders where appropriate.
Guidelines	The Guidelines provide information and guidance on particular topics relevant to the construction industry. The CIC expects all industry stakeholders to adopt the recommendations set out in the Guidelines where applicable.
Codes of Conduct	The Codes of Conduct set out the principles that all relevant industry participants should follow. Under the Construction Industry Council Ordinance (Cap. 587), the CIC is tasked to formulate codes of conduct and enforce such codes. The CIC may take necessary actions to ensure compliance with the codes.

If you have read this publication, we encourage you to share your feedback with us. Please take a moment to fill out the Feedback Form attached to this publication in order that we can further enhance it for the benefit of all concerned. With our joint efforts, we believe our construction industry will develop further and will continue to prosper for years to come.

ABBREVIATIONS

BIM	Building Information Modelling
CAD	Civil Aviation Department
CMOS	Complementary Metal Oxide Semiconductor
DSM	Digital Surface Model
DTM	Digital Terrain Model
GCP	Ground Control Point
GIS	Geographic Information System
GNSS	Global Navigation Satellite System [#]
GSD	Ground Sampling Distance
HDR	High Dynamic Range
LiDAR	Light Detection and Ranging
PPK	Post-Processed Kinematic
RPS (LS)	Registered Professional Surveyor (Land Surveyor)
RTK	Real-Time Kinematic
UAS	Unmanned Aircraft System

[#]Global Navigation Satellite System (GNSS) is a general term for various satellite constellation systems for positioning, navigation, and timing services (e.g. Global Positioning System, GPS (United States), GLONASS (Russia), Galileo (European Union), and BeiDou (Mainland China)).

1. INTRODUCTION

Unmanned Aircraft System (UAS) services for image capturing and surveying can help to capture data with increased value and efficiency when compared with the traditional surveying methods, which are labour intensive. UAS offers the ability to capture high quality data at a much lower cost. It can cover more ground areas in less time without sacrificing accuracy. It also reduces or eliminates risks for personnel having to work in dangerous areas and hence improves safety performance in construction projects.

This publication presents sample specification clauses that can be adopted/adapted for the procurement of services for image capturing and surveying by UAS. It is written to provide reference materials for competent professionals in the preparation of contracts.

The sample specification clauses should be modified or added, where necessary, for the preparation of a particular specification, to suit the requirements of each individual project. Notes are given in italics against some of the clauses on the issues to be considered or factors to be taken into account in finalising the contract requirements.

Practitioners are encouraged to apply to the CIC to seek funding support under the Construction Innovation and Technology Fund (CITF²). Reference should be made to the CIC's CITF website on the pre-approved lists of technologies under the different categories (<http://www.citf.cic.hk/?route=search>). The website provides details of technological solutions that may be applicable in construction projects as well as information on relevant service providers.

As technologies advance rapidly, it is crucial to consult service providers on their latest technological solutions when preparing specifications. In particular, the italicised text in the specification clauses of this publication should be reviewed and updated, where appropriate. Appropriate functional requirements should be included in the specifications to meet the needs of the project and to derive value for productivity improvement and cost effectiveness.

² *The CITF was established by the HKSAR Government to encourage wider adoption of innovative constructive methods and new technologies in the construction industry. The CITF provides funding support to consultants, levy paying contractors, registered specialist trade contractors and registered subcontractors to adopt new technologies in their Hong Kong construction projects. For details, please refer to the CITF website at www.citf.cic.hk. Please note that applications for CITF should be made before committing expenses. Technology will only be approved where it is found to meet the objectives of the CITF after assessment by the relevant Vetting Sub-Committee.*

2. SAMPLE SPECIFICATION CLAUSES FOR PROVISION OF IMAGE CAPTURING AND SURVEYING SERVICES BY UNMANNED AIRCRAFT SYSTEMS

2.010 General Requirements

- (1) The Contractor shall provide the services required himself or employ a competent service provider to provide the service.
- (2) The Contractor shall provide, install and operate unmanned aircraft systems (UAS) for condition survey of features and objects (*and for measurement, if required*) as required by the Architect/Engineer and as listed in **Table 1**.

(Note: The term “Architect/Engineer” may be changed to other terms to suit different project situations. For example, “Supervising Officer”, “Contract Manager”, and “Appointing Party”, etc., may be used as appropriate.)

- (3) The Contractor shall provide all manpower, equipment and transportation (including marine transport if necessary) for the UAS service.
- (4) The Contractor shall ensure that a unique identification mark is clearly shown on the UAS adopted in the Contract, and provide the Architect/Engineer with information on the UAS owner (name of person or company and contact details) so that the UAS owner can be contacted if necessary on enquiries or matters related to the UAS service provided.
- (5) The Contractor shall submit his proposal for the UAS surveying services, the hardware and software to be used (e.g. the UAV take-off weight, propeller size, battery, camera and associated lens, ground station computer, etc.) and the operation (e.g. maximum flight time, suitable mapping extent, etc.) for approval by the Architect/Engineer.
- (6) The Contractor shall submit digital files of the videos and photographs (*and other digital data captured, if required*) in a format that complies with *Clauses 2.070, 2.080 and/or 2.090* and any further requirements agreed with the Architect/Engineer.
- (7) For land surveying services requiring professional surveyor input, the survey accuracy and results in the reports shall be checked and certified by a Registered Professional Surveyor (Land Surveying) registered under the Surveyors Registration Ordinance (Cap. 417).
(Note: For surveying targets other than land/terrain (e.g. isolated buildings), other technical or professional input to the surveying reports may be required.)
- (8) The Contractor shall procure insurance to indemnify the Employer against any claims, proceedings, costs, losses, damages and expenses arising out of the provision of the UAS service.
- (9) The Contractor shall ensure that all requirements under the Personal Data (Privacy) Ordinance (Cap. 486) have been duly complied with in relation to the data/information collected.

2.020 Experience

- (1) The Contractor shall provide job references to show that he has conducted relevant UAS surveying services in the Hong Kong SAR

Requirements

within the *past 3 years*.

- (2) The Contractor shall submit to the Architect/Engineer the curriculum vitae of a key person responsible to oversee the UAS operation and monitor safety during flights of the unmanned aircraft. This person shall either have *at least three years of experience* in land surveying services and *at least one year of experience* in undertaking UAS surveying services (including photogrammetry processing where specified), or have a recognised degree in land surveying.
- (3) The Contractor shall also submit to the Architect/Engineer the training records required by the Civil Aviation Department (CAD) for the UAS pilot proposed to control and operate the unmanned aircraft.

2.030

Permissions by the Civil Aviation Department

- (1) The Contractor shall comply with the requirements stipulated in the Small Unmanned Aircraft Order under the Civil Aviation Ordinance (Chapter 448) and the other relevant regulations or orders, in particular the following clauses under this Clause 2.030.
- (2) The Contractor shall follow the application procedures for flying UAS stipulated by the CAD.
- (3) The Contractor shall be responsible for the CAD permit application and arrangement of any site visits/demonstrations to facilitate the application. The demonstrations shall be carried out by the proposed UAS pilot and shall include pre-flight checks (including secured mounting), take-off procedure, inflight procedure, landing procedure and post-flight checks, adhering to the requirements set by the CAD.
- (4) The Contractor shall submit all relevant application and the required documents (e.g. operation manual, flight plan, insurance certificate, etc.) to fulfil the CAD's requirements prior to the proposed deployment of the UAS. For preparation of the flight plan and operation manual, etc., the Contractor shall take into account the mitigation measures for possible disturbance / loss of control due to inclement weather (e.g. sudden thunderstorm, windy conditions, etc.). A copy of all the submitted forms shall be provided to the Architect/Engineer.
- (5) Prior to applying to the CAD, the Contractor shall submit to (and agree with) the Architect/Engineer relevant details of the UAS flying and data capture plan (including the proposed date, time, flight paths, UAS details, and image and data capture requirements). The Contractor shall show clearly the operating requirements for the aerial surveying. The maximum speed of the UAS and the maximum flying altitude shall be defined appropriately to meet the requirements set by the CAD to determine the minimum lateral separation from uninvolved people / structures / vehicles / vessels (if they are near the aerial surveying zone).
- (6) Any person proposed to be a UAS pilot under the Contract shall meet the requirements of the CAD.
- (7) The Contractor shall always observe the general safety guidelines and safety parameters stipulated by CAD at its website:
https://www.cad.gov.hk/english/Unmanned_Aircraft_Systems.html.

(Note: Reference should be made to the "Small Unmanned Aircraft ("SUA") Regulatory Requirements at this website:

- 2.040 Liaison with Stakeholders
- (1) The Contractor shall liaise with all relevant stakeholders as necessary to facilitate the UAS deployment, including (but not limited to) transport operators, utility providers, property management parties and government departments.
(Note: Examples of relevant stakeholders may include Regional Offices of the Transport Department, Highways Department, and Hong Kong Police Force, etc., where the surveying is conducted in close proximity to public roads adjacent to the aerial surveying zone.)
 - (2) The Contractor may seek assistance from the Architect/Engineer or the Employer to obtain relevant land owners' consent for meeting the CAD permit requirements.
- 2.050 Provision of Training Course
- (1) The Contractor shall provide a training course on the proposed UAS service to personnel nominated by the Architect/Engineer. The details are as follows *(Note: These requirements may be amended depending on the needs of the Architect/Engineer and CAD)*:
 - (a) The course duration shall be *two days (8 hours each)*, for 2 – 5 trainees (*x professional staff and y technical staff*).
 - (b) The course content shall cover key aspects of the field operations, UAS safety requirements, data acquisition and data-processing for the UAS surveying services.
 - (c) Training material in digital format shall be provided.
 - (d) The course content shall be proposed to (and agreed by) the Architect/Engineer prior to commencement of the training course.
 - (e) Trainers shall possess extensive knowledge and practical experience in deploying UAS for surveying and analysing data collected by UAS.
 - (f) The training course shall be arranged within a period agreed with the Architect/Engineer.
 - (g) The training venue and associated computer facilities shall be provided by the Architect/Engineer.
- 2.060 UAS for Capturing Images
- (1) The UAS shall be equipped with a GNSS positioning system (e.g. Real-Time Kinematic (RTK), Post-Processed Kinematic (PPK), etc.) that will allow direct geo-referencing of locations where the images are captured to a level of precision and accuracy as specified by the Architect/Engineer.
(Note: The accuracy of network RTK is about 3 – 5 cm.)
 - (2) The UAS shall be capable of surveying and capturing images of the entire exposed surfaces of all features and objects as required by the Architect/Engineer.
 - (3) The UAS shall be capable of capturing moving images (videos) and still images (photographs) according to the requirements agreed with the Architect/Engineer.
 - (4) The UAS shall be capable of capturing videos and photographs to show

sufficient details of feature and object surfaces with a sufficient level of visibility *(to allow measurement to within x mm, if quantitative measurement is required, e.g. crack widths or infrared intensity levels)* as specified by the Architect/Engineer.

- (5) The UAS shall be capable of moving in any direction to capture videos and photographs. It shall be capable of flying to a distance of x m in the horizontal direction and a height of y m in the vertical direction from the location of control.

(Note: x and y shall be specified by the Architect/Engineer. If flying within confined spaces is required (e.g. within a utility tunnel), special arrangements for capturing the image locations shall be made.)

- (6) The Contractor shall provide the Architect/Engineer with a software for real-time display (or immediate replay) of videos recorded during a UAS survey using equipment at the premises of the Architect/Engineer.

- (7) The photographs taken by the UAS shall meet the following requirements:

- (a) Minimum effective number of pixels: *12 million*
- (b) Format: *JPEG / DNG (RAW)*
- (c) Support High Dynamic Range (HDR) photo
- (d) Other specifications as necessary to provide a sufficient Ground Sampling Distance (GSD) for specific feature detection.

- (8) The videos taken by the UAS shall meet the following requirements:

- (a) Minimum effective number of pixels: *12 million*
- (b) Minimum resolution: *FHD: 1920 x 1080*
- (c) Support HDR video
- (d) Other specifications as necessary to provide a sufficient GSD for specific feature detection.

(Note: The above requirements may be modified by taking into account the objectives of the UAS surveying service required, and consultations with vendors (if needed) on the latest developments regarding functional capabilities of commercially available UAS.)

2.070
Deliverables

- (1) After each UAS flight/survey, the Contractor shall submit to the Architect/Engineer reports in digital format to cover the service provided after each UAS flight/survey. The reporting time shall be agreed with the Architect/Engineer.

(Note: The Architect/Engineer may request the Contractor to upload the digital reports to a designated digital platform such as a CDE.)

- (2) The reports shall include the date, time, flight paths, UAS details, a plan showing the locations (from where photogrammetric images are taken and the ground control points adopted for geo-referencing (in both pdf and dxf/dwg/dgn file formats)), the data captured (with the photographs and videos referenced to the exact locations of the features/objects surveyed), and comments on the limitations of the service and accuracy

of the data captured.

- (3) The reports shall be accompanied by a USB flash drive (or other suitable storage device for the photographs and videos taken during the survey). The reports shall include suitable links to the photographs and videos.

2.080 UAS with Camera Equipment for Nadir and Oblique Photogrammetry (Optional)

- (1) The Contractor shall convert all photogrammetric images captured by the UAS to geo-spatial data using suitable software such that the output geospatial data (including orthomosaics, DSM, DTM, point cloud and contours) can be used for producing BIM or other 3D models (e.g. 3D-GIS models). The Contractor shall submit the data in a file format compatible with the 3D modelling software specified by the Architect/Engineer.

- (2) The Flight Controlling System of the UAS shall meet the following requirements:

- (a) Mission planning functionality for auto 3D fly path generation for the surveying-grid flying mode.
- (b) Ability to undertake autonomous flights at varying altitudes following the site topography.

(Note: For safety reasons, autonomous flight is not recommended in most urban environments.)

- (c) Auto triggering of the camera according to a pre-defined interval.
- (d) Provision of a fail-safe system when required. The safety control measures shall be approved by the Architect/Engineer.

(Note: The Contractor shall be responsible for IT security if the UAS flight control system provided is connected to the Client's IT system. For government projects, the Contractor shall comply with the relevant Government IT security regulations, policies and guidelines.)

- (3) The images captured by the UAS shall meet the following requirements:
 - (a) Images taken must include nadir (vertical) or oblique aerial imagery.
 - (b) Minimum effective number of pixels: 12 MP for each CMOS sensor.
 - (c) Format: *JPEG or any other raw format.*
 - (d) Minimum forward overlapping extent of each set of images is 60% along each fly path of the UAS.
 - (e) Minimum sideward overlapping extent of adjacent sets of images is 60% along each fly path of the UAS.
 - (f) Minimum GSD size should be kept within a reasonable cm or mm range to reflect existing ground features with reasonable accuracy with due respect to safety concerns.

(Note: The above requirements may be modified by taking into account the objectives of the UAS surveying service required, and consultations with vendors (if needed) on the latest developments regarding functional capabilities of commercially-available UAS.)

2.090 UAS with LiDAR Scanner and Equipment

- (1) If LiDAR Scanner and Equipment is attached to the UAS, it shall meet the following requirements:

- (a) 3D mesh format of the modelled result shall be in OSGB, LODTree,

for Generating
3D Information
(Optional)

FBX or OBJ format (depends on final application).

- (b) Adoption of the Hong Kong 1980 Grid as the reference for the horizontal (XY) coordinate system.
- (c) Adoption of the Hong Kong Principal Datum as the reference for the vertical (Z) coordinate system.
- (d) Relative accuracies of $\pm 10\text{cm}$ for XY and $\pm 15\text{cm}$ for Z by a Ground Control Point (GCP) measurement tool.

(Note: The above requirements may be modified by taking into account the objectives of the UAS surveying service required, and consultations with vendors (if needed) on the latest developments regarding functional capabilities of commercially-available UAS. Other equipment can be attached to the UAS for conducting a surveying service to suit a specific type of inspection (e.g. infrared thermal camera equipment to suit specific inspection use.))

- (2) The digital data obtained by the UAS shall meet the following requirements:

(Note: The data type and format required should be specified by the Architect/Engineer. For producing BIM models (e.g. for measurement of excavation volumes) and producing as-built records (e.g. for utility services before they are covered up), the following clause could be considered.)

- (a) If the digital data captured are used to produce BIM models to a required Level of Information Need (LOIN) using software specified by the Architect/Engineer (to an accuracy of $x\text{ mm}$ and $y\text{ mm}$ in the horizontal and vertical direction respectively), the software shall comply with the requirements in the relevant BIM Standards published by the Construction Industry Council.

(Note: The relevant software and standards should be specified by the Architect/Engineer. For the definition of LOIN and details of implementation, reference shall be made to the “CIC BIM Dictionary (December 2020) and Section 2 of the CIC BIM Standards – General (Version 2 – December 2020)” respectively.)

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