

# Accuracy assessment of small UAS surveys and the role of GCPs with and without GNSS-PPK positioning

**Dimitrios Bolkas**

Assistant Professor, Department of Surveying Engineering, The Pennsylvania State University, Wilkes Barre Campus, 1269 Old Route 115, Lehman, PA 18627, USA. E-mail: [dxb80@psu.edu](mailto:dxb80@psu.edu)

**Abstract:** Topographic datasets acquired from small unmanned aerial systems (sUASs) can achieve high accuracy (~ 1-2 cm), however, this depends on several factors e.g., flying altitude, camera type and (self-)calibration, number of ground control points (GCPs), shadow areas, image network geometry, image-matching performance, etc. Therefore, the spatial distribution of elevation errors can greatly vary and will depend on such factors. The main objective of this study is to understand the impact of GCPs and global navigation satellite system post processed kinematic (GNSS-PPK) on the accuracy of sUAS surveys. This study assesses the impact of GCP number (and their separation distance) on elevation accuracy, as well as their impact on geo-referencing and camera self-calibration. Moreover, this study assesses the contribution of GNSS-PPK on geo-referencing and camera self-calibration. Aerial imagery is collected from two flights, with GNSS-PPK capability and 23 GCPs, at 90-m and 50-m altitudes (1.9 cm and 1.1 cm average point spacing, respectively). Reference elevation information is derived from terrestrial laser scanning and checkpoints collected using total stations. Results show that, when geo-referencing relies on GCPs, at least 8-12 GCPs (85 m to 65 m distance separation) are needed to achieve reliable geo-referencing and camera self-calibration for this study area and data. This leads to an elevation accuracy at the 1-2 cm. However, when GNSS-PPK is combined with GCPs the required number of GCPs drops to 4-5 (120 m to 105 m separation distance) in order to achieve the same accuracy level as the GCP-only case. Of note is that complex areas (such as triangular roofs and dome shapes) achieve lower accuracy i.e., 5-10 cm, and the number of required GCPs to reach this accuracy level is higher (12-16 for GCP-only and 6-8 for GCPs+GNSS-PPK geo-referencing). Results and conclusions of this study can assist practitioners in sUAS survey planning.