GRYFN CERTIFICATE OF GEOMETRIC CALIBRATION

# CALIBRATION IDENTIFICATION

|  |  |
| --- | --- |
| CALIBRATION REFERENCE ID |  |

# SYSTEM SPECIFICATION

|  |  |  |
| --- | --- | --- |
|  | MODEL NAME | SERIAL NUMBER |
| GRYFN System |  |  |
| GNSS/INS Unit |  |  |
| VNIR Hyperspectral Scanner |  |  |
| SWIR Hyperspectral Scanner |  |  |
| LiDAR |  |  |
| RGB camera |  |  |

# CALIBRATION DATASETS

|  |  |  |
| --- | --- | --- |
| CALIBRATION FLIGHT | | |
| GENERAL INFORMATION | Date |  |
| Location |  |
| Sensor |  |
| FLIGHT CONFIGURATION | Flying heights |  |
| Ground speed |  |
| WEATHER CONDITION | Wind speed |  |
| Temperature |  |
| Sky condition |  |
| GROUND CONTROL | Number of GCPs | 11 |
| Horizontal accuracy | ±2 to ±3 cm |
| Vertical accuracy | ±3 to ±4 cm |

A black signature on a white background

AI-generated content may be incorrect.A close-up of a signature

AI-generated content may be incorrect.

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STAFF CERTIFICATE SIGNATURE CERTIFICATE APPROVAL SIGNATURE

# GEOMETRIC CALIBRATION OVERVIEW

## OBJECTIVE

The goal of calibration is to determine the intrinsic parameters and extrinsic parameters for each onboard sensor.

Intrinsic parameters are inherent properties of each sensor. For example, the intrinsic parameters of an RGB camera typically include the focal length, principal point coordinates, and lens distortion. In GRYFN calibration, the intrinsic parameters for each sensor are as follows:

* Hyperspectral scanner: Focal length
* LiDAR: Intrinsic parameters provided by the manufacturer
* RGB camera: Focal length, principal point coordinates, and lens distortion

Extrinsic parameters (mounting parameters) describe the relative position (hereafter, lever arm) and orientation (hereafter, boresight) of each sensor with respect to the GNSS/INS unit. In GRYFN calibration, the lever arm components are measured with precision using CAD design drawings. The boresight angles are initially estimated based on system design values and are subsequently refined through the calibration process.

## DATA ACQUISITION

The calibration flight takes place in an open area with flat terrain. Flight configuration is carefully designed to achieve optimal calibration results. Key considerations include opposite flying directions, varying flying heights, and significant lateral separation between flight lines.

In addition to the flight, an independent ground control survey is performed. Several checkerboard targets are deployed at the site, and the coordinates of the target centers are surveyed using Real-Time Kinematic-Global Navigation Satellite Systems (RTK-GNSS). These target centers serve as ground control points (GCPs).

The calibration process uses data acquired from the calibration flight and ground control survey.

## PROCEDURE

Push-broom hyperspectral scanner: The image coordinates of the GCPs are manually measured. The boresight angles and focal length are refined through a nonlinear optimization process that ensures the collinearity of light rays connecting the scanner’s perspective center, the GCPs, and their corresponding image points.

LiDAR: Thin, sliced profiles are extracted along and across the flight direction and used as calibration primitives. The boresight angles are refined through a nonlinear optimization process that minimizes discrepancies between profiles from different flight lines.

RGB camera: The image coordinates of the GCPs are manually measured. A bundle adjustment is conducted to refine the boresight angles and the intrinsic parameters (including focal length, principal point coordinates, and lens distortion).

# VNIR HYPERSPECTRAL SCANNER CALIBRATION RESULTS

## SENSOR SPECIFICATION

|  |  |
| --- | --- |
| MODEL NAME |  |
| SERIAL NUMBER |  |
| LENS |  |
| IMAGE WIDTH (PIXEL) |  |
| PIXEL SIZE (µm) |  |
| NOMINAL FOCAL LENGTH (mm) |  |

## CALIBRATION RESULTS

|  |  |  |
| --- | --- | --- |
| INTRINSIC PARAMETERS | Focal length (mm) |  |
| MOUNTING PARAMETERS | Lever arm X (m)\* |  |
| Lever arm Y (m)\* |  |
| Lever arm Z (m)\* |  |
| Boresight ω (°) |  |
| Boresight φ (°) |  |
| Boresight κ (°) |  |

\* Measured from CAD design drawings

## QUANTITATIVE EVALUATION

|  |  |
| --- | --- |
|  | RESULT |
| RMSE X (m) |  |
| RMSE Y (m) |  |

# SWIR HYPERSPECTRAL SCANNER CALIBRATION RESULTS

## SENSOR SPECIFICATION

|  |  |
| --- | --- |
| MODEL NAME |  |
| SERIAL NUMBER |  |
| LENS |  |
| IMAGE WIDTH (PIXEL) |  |
| PIXEL SIZE (µm) |  |
| NOMINAL FOCAL LENGTH (mm) |  |

## CALIBRATION RESULTS

|  |  |  |
| --- | --- | --- |
| INTRINSIC PARAMETERS | Focal length (mm) |  |
| MOUNTING PARAMETERS | Lever arm X (m)\* |  |
| Lever arm Y (m)\* |  |
| Lever arm Z (m)\* |  |
| Boresight ω (°) |  |
| Boresight φ (°) |  |
| Boresight κ (°) |  |

\* Measured from CAD design drawings

## QUANTITATIVE EVALUATION

|  |  |
| --- | --- |
|  | RESULT |
| RMSE X (m) |  |
| RMSE Y (m) |  |

# LIDAR CALIBRATION RESULTS

## SENSOR SPECIFICATION

|  |  |
| --- | --- |
| MODEL NAME |  |
| SERIAL NUMBER |  |

## CALIBRATION RESULTS

|  |  |  |
| --- | --- | --- |
| MOUNTING PARAMETERS | Lever arm X (m)\* |  |
| Lever arm Y (m)\* |  |
| Lever arm Z (m)\* |  |
| Boresight ω (°) |  |
| Boresight φ (°) |  |
| Boresight κ (°) |  |

\* Measured from CAD design drawings

## QUALITATIVE EVALUATION

Figure 1: Sample point cloud profiles side view before and after calibration.

|  |  |
| --- | --- |
| Before calibration | After calibration |
|  |  |
|  |  |

## QUANTITATIVE EVALUATION

|  |  |
| --- | --- |
|  | RESULT |
| PLANE FITTING RMS (m)\* |  |

\* Evaluated using a planar segment on the ground

# RGB CAMERA CALIBRATION RESULTS

## SENSOR SPECIFICATION

|  |  |
| --- | --- |
| MODEL NAME |  |
| SERIAL NUMBER |  |
| LENS |  |
| IMAGE WIDTH (PIXEL) |  |
| IMAGE HEIGHT (PIXEL) |  |
| PIXEL SIZE (µm) |  |
| FOCAL LENGTH (mm) |  |

## CALIBRATION RESULTS

|  |  |  |
| --- | --- | --- |
| INTRINSIC PARAMETERS | xp (pixel) |  |
| yp (pixel) |  |
| c (pixel) |  |
| k1 (pixel-2) |  |
| k2 (pixel-4) |  |
| k3 (pixel-6) |  |
| p1 (pixel-1) |  |
| p2 (pixel-1) |  |
| MOUNTING PARAMETERS | Lever arm X (m)\* |  |
| Lever arm Y (m)\* |  |
| Lever arm Z (m)\* |  |
| Boresight ω (°) |  |
| Boresight φ (°) |  |
| Boresight κ (°) |  |

\* Measured from CAD design drawings

## QUANTITATIVE EVALUATION

|  |  |
| --- | --- |
|  | RESULT |
| RMSE X (m) |  |
| RMSE Y (m) |  |
| RMSE Z (m) |  |