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UAS PROCESSING, FROM SENSOR TO EXPLOITATION

POWER PORTFOLIO PROCESSING

White Paper
January 09, 2015

Overview

There's no question that Unmanned Aerial Systems (UAS) in combination with the various sensors they are capable of carrying are fundamentally changing the geospatial marketplace. The emerging technologies that make these systems not only possible, but also affordable and accessible, are still at a relatively early stage of development. Even so, opportunities to use these systems abound.

For an organization looking to enter into the UAS market as a producer and distributor of data, the choice of which aerial platform system or systems to use can be a difficult one. Many factors need to be considered, some of which include fixed vs. rotary wing aircraft, the versatility of the system, the system's maximum time aloft, the range of weather conditions the aircraft can safely operate within, flight crew training requirements, transporting the system, and of course, the regulations imposed on the operator of the system.

Along with all of these choices, one must also find a reliable and cost effective means of processing and disseminating the data they collect. This data comes in a wide variety of formats and sources, including aerial imagery, point clouds, multispectral or hyperspectral imagery, and any number of other sensors that can be sent aloft.

Background

- These Unmanned Aerial Systems are comprised of both the Unmanned Aerial Vehicles (UAVs) and the on-board sensors that capture the data. In order to be transformed into an exploitable format, the data must then be processed through photogrammetric and remote sensing software.
- Again, many factors need to be considered for not only producing nice orthorectified images or orthomosaics, but also for utilizing stereo models to create value added products like Digital Terrain or Digital Surface Models (DTMs, DSMs). However, there are many uncertainties in workflows which produce accurate and functional products. The selection of UAV and the sensor creates downstream processing considerations which must be taken into account from a software perspective. For instance, a higher flying altitude might yield a smaller image footprint, which in turn can affect how many points are collected across images. Storage of the data may not be as great a concern these days, but the management and dissemination of the massive quantities of images can be difficult to track. Hexagon has the resources to bring together a complete, end-to-end workflow from mission planning and data capture to production and delivery of geospatial end products.
- From the hardware side, Hexagon companies offer great UAVs such as the Aibotix, Aibot X6 Multi-copter, which is capable of carrying up to a 4.5 kg payload. We also offer the Swiss Drones Dragon 50, which can carry a 35 kg payload like the Leica RCD 30 medium format aerial camera. Couple that with a Leica RTK GPS receiver on board the UAS and perhaps a MS50 multi-station (which is a combination laser scanner and total station for ground control collection) and you will feed the software side with ultra-high accuracy metadata input, resulting in a greater chance of successful imagery output.
- After data collection, the data processing can be done using Hexagon Geospatial software such as ERDAS IMAGINE®. This is available as a standalone workstation, on a cloud server, or even in near real-time with an active download link from the UAS. The data products can then be cataloged using ERDAS APOLLO and from there disseminated as flat files, OGC web services, ECW data streaming, or published from the spatial modeling environment as part of a Hexagon Geospatial Web Processing Service.

Abstract

In this paper, we look at one way of putting all these intricate pieces together. Although it is perhaps a daunting task, streamlining and integrating the workflow using Hexagon technologies provides the perfect solution for all or any of the steps. GEOSYSTEMS, Hexagon Geospatial's long-time partner, has come up with a workflow that does exactly this. By collecting imagery from a UAV like the Aibot X6 Multi-copter, along with correlation software

operators inside the ERDAS IMAGINE Spatial Modeler and disseminating the results as web services to any web ready GIS or any web portal, such as the Hexagon Geospatial Portal.

- The challenge is to have all these workflow parts synchronized. All of the input parameters must be dialed in and be as accurate as possible, thereby minimizing any trickle-down processing that can propagate error. Hexagon technology has the capability to resolve this. We will demonstrate how this can be done with the utmost accuracy by exploiting this UAS imagery across the entire workflow, from sensor to exploitation.

This market is exploding world-wide and, in places such as in the United States where the regulations are only beginning to loosen, the demand can only increase.

UAV Data Capture

Geospatial applications of UAS include area-based mapping, agriculture applications, inspection and monitoring of bridges, dams, power and radio transmission towers, to name just a few. These platforms include not only fixed and rotary wing aircraft, but in some cases, even hot air balloons. These systems can vary widely in size, weight, and complexity, from converted jetliners all the way down to small, handheld aircraft weighing less than 20 kg. In the near term at least, the majority of UAS will likely be less than 11 kg (~25lbs), which adheres to the current US FAA regulations for those with a Certificate of Authorization (COA) to fly. The choice of UAV type within this weight class depends on many factors including:

- The dimensions, power requirements, and weight of the sensor.
- How versatile does the UAS need to be?
 - Fixed wing aircraft tend to have a smaller range of sensors they can accept, due to weight and balance issues. On multi-rotor aircraft, the sensor is generally mounted directly above or below the aircraft's center of gravity so balancing the aircraft is not an issue.
- Is the aircraft going to be used for point inspections, for area mapping, or both?
 - Fixed wing aircraft are better at performing wide area mapping, but are generally not suitable for detailed inspection of fixed objects like bridges, dams, and power transmission towers.
 - Multi-rotors like the Aibot X6 and helicopters do well at inspection tasks, but generally have a shorter flight time than fixed wing aircraft.
 - Fixed wing aircraft require an extended takeoff and landing area whereas multi-rotors and helicopters take off and land vertically.
- If performing area based mapping, how large of an area needs to be covered, and how quickly?
 - Out of necessity, fixed wing aircraft generally fly faster than rotary aircraft.
- Will the UAS be flying in adverse or windy weather conditions?
 - Fixed winged aircraft are more susceptible to yaw, pitch and roll from wind.
- Does the aircraft need to remain stationary for some amount of time?
- Does the aircraft need to adhere to a rigidly defined flight path or area?

- What are the crew training requirements?
- How complex is it to operate and maintain the system?
- How easily is the system transported?
- Are there government regulations regarding the operation of the system?

Fixed wing aircraft have the advantage of lower power requirements, which translates into longer flying times and larger coverage areas from a single flight. The benefit of rotary winged aircraft like helicopters and multi-rotors is that they can remain stationary and fly a precise pattern. Fixed wing aircraft require extra room in their flight plan for making turns, take offs, and landings. Generally, multi-rotors and balloon aircraft are lower in complexity and easier to maintain than their helicopters and fixed wing counterparts. The Hexagon Multi-rotor UAV options are the SwissDrones Dragon 50 (large payload) copter, which is more conducive to large area coverage and the smaller payload Aibotix Aibot X6. For the purposes of this paper, we will focus on the Aibotix X6.

The Position Accuracy

Positional accuracy is of primary importance when collecting geospatial imagery. Achieving the most accurate results means painstakingly collecting accurate accuracy measurements all along the workflow. Many factors also become involved when ensuring the utmost positional accuracy. Because it affects everything downstream in the workflow, any marginally significant errors in any one of the factors listed below can propagate itself throughout the entire workflow. A prime example is poor calibration. Something as simple as a data entry error when entering the sensor's focal length can adversely affect the accuracy of flying height calculation, GCP collection, tie point collection and cause significant triangulation errors.

Below is a list of factors that can affect accuracies and a solid solution.

- **Accuracy** and collection rate of GPS recording
- **Accuracy** and collection rate of IMU recording
- **Time difference** of acquisition, GPS and IMU recording trigger time offsets
- Values of camera **calibration**
- Focal length
- Lens distortion
- **Flight height** – Building lean decreases with increasing flight height
- **Payload** limits the GPS and IMU choice
- **Stability** of platform

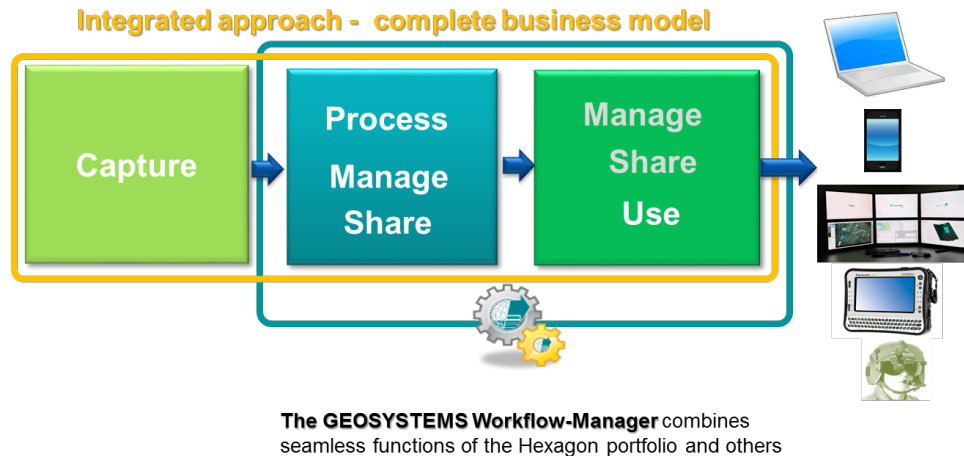
UAS Business Model

There are three major components to establishing an economically sound and successful business with UAS data:

- **Capturing:** The UAV, normally either a multi-rotor or a fix-wing "drone," equipped with appropriate sensors, GPS/RTK technology and a flight path program.
- **Processing:** Suitable data processing software or functions to produce GIS-ready datasets like orthophotos and/or digital terrain models (DTM).

- **Integrating:** The data must be able to be integrated into customer application. This component is highly dependent on the customer's demand on the UAS data or the derived information. To fulfill this demand in general, the data dissemination can be provided as standardized web services.

Only a highly efficient combination of all components ensures that the UAV technology can be utilized to create a successful UAS business model. Based on standard components, GEOSYSTEMS have built a UAS workflow using Hexagon technologies that ensures a fully automated UAV data processing and dissemination. The UAS workflow covers the complex integration from image processing to dissemination of results in a standardized and state-of-the-art technology.



Our solution provides for seamless, automated processing of all necessary operations. In addition, we do not simply provide the resulting data as disk full of flat files (which will cause problems at the customer side), but as a metadata-rich OGC web services and streaming ECWP. The end user gets hassle free results, which can easily be deployed and used throughout all OGC-enabled desktop and web client packages. There are a variety of workflows from providing basic products and services to a more flexible and adaptable version which empowers a robust near-real-time approach for some UAS constellations.

The GEOSYSTEMS UAS Workflow

The mission planning and selection of an area of interest of course varies from project to project, but even across a variety of UAS mission plans, the output from the UAS remains fairly constant. Because of this, this paper will focus on the processing and dissemination of the data.

After a successful UAS flight, the GEOSYSTEMS workflow manager checks for new images and flight information (e.g. camera calibration, GPS/IMU information). If those are found, it uses the customer's defined processing profile and automatically starts running the processing steps for photogrammetry, image processing and image cataloguing. Having a robust Remote Sensing and Photogrammetry package such as ERDAS IMAGINE at your disposal, can help overcome obstacles. Here is a hi-level overview of the workflow:

- UAV **collection** requires flight-relevant metadata (like GPS/IMU) to define the workflow.
- After collection, the data must be processed by photogrammetry and image **processing** software, such as ERDAS IMAGINE from Hexagon Geospatial. If required, the workflow allows the functions of other software functions, such as Agisoft's Photoscan Professional for GEOSYSTEMS, to be integrated. The results of these processing steps are orthoimages and/or orthomosaics, point clouds, or rasterized surface models.

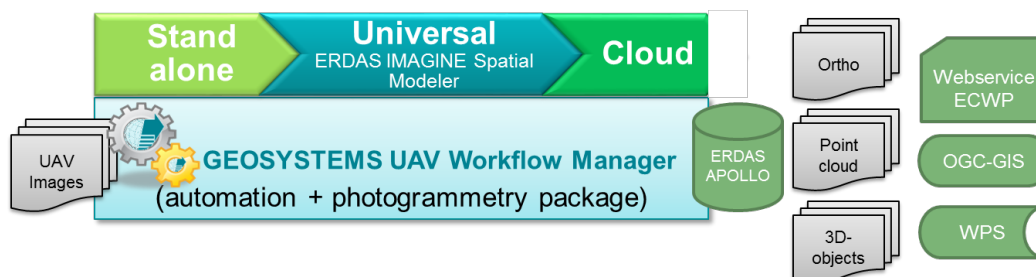
- After processing, all of the data products are **catalogued** in ERDAS APOLLO. The catalog harvests all of the imagery metadata so the data can be easily located and accessed. The data can then be disseminated as flat files, OGC web services, streaming ECW images, or used as part of Hexagon Geospatial Web Processing Service, which is a mechanism for creating value-added products over the web.



Workflow Flavors

The Spatial Modeling environment in ERDAS IMAGINE is tremendously modular and flexible, which allows many different configurations of the workflow. GEOSYSTEMS provides a suite of fully-automated UAV-workflows, based on a workflow manager. This makes the portfolio scalable, customizable, flexible and affordable.

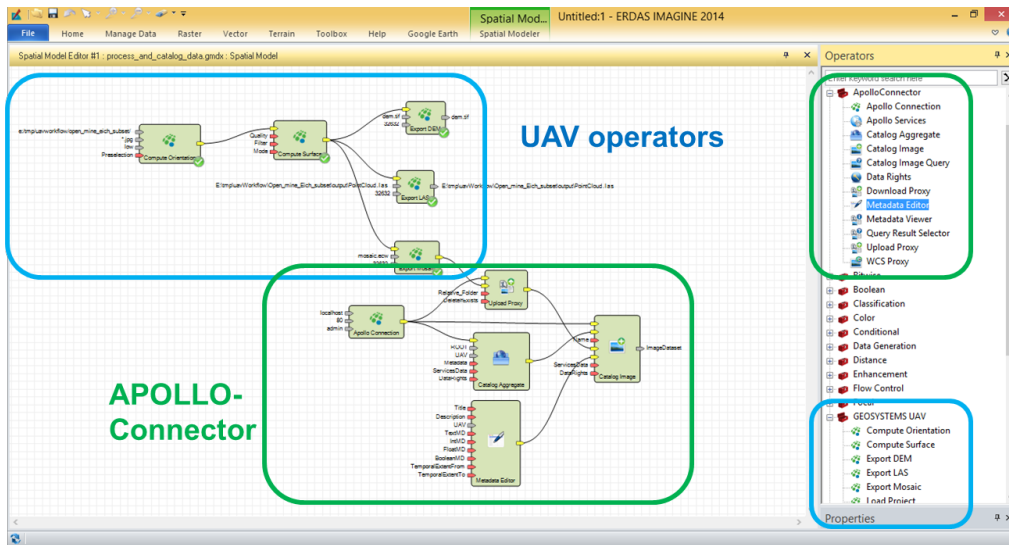
- Standalone:** Creates orthomosaic, DEM and LAS point cloud as file and OGC-web service.
- Universal:** (based on ERDAS IMAGINE Spatial Modeler) Adds additional distributed processing and functionality as well as automated cataloguing.
- Cloud:** Provides a specific UAS-customer upload portal.
- Near real-time:** High-speed data processing (needs down-link ability).



Universal UAS Architecture

The universal UAS workflow takes advantage of the ERDAS IMAGINE Spatial Modeler technology and the flexibility to enrich the Spatial Modeler library through the available SDK.

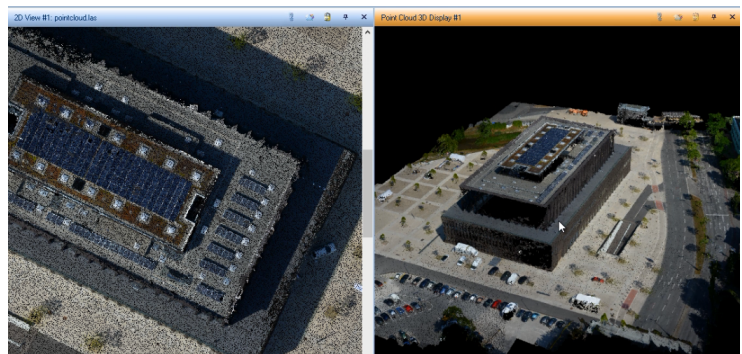
Based on this technology, we added the UAV-relevant photogrammetric functions to the Spatial Modeler Library as part of this dedicated workflow. Access to the advanced image processing and batch processing functions allow for the seamless integration of the processing results. Additionally, the connection to ERDAS APOLLO is also available as Spatial Modeler functions, further streamlining this workflow. This specialized UAV application allows it to run all necessary UAV-specific functions within the spatial modeller, including point cloud functions such as RGB encoding, Classification, etc. This enables a fully-customizable customer-defined processing chain that can be built, applied, and completely automated.



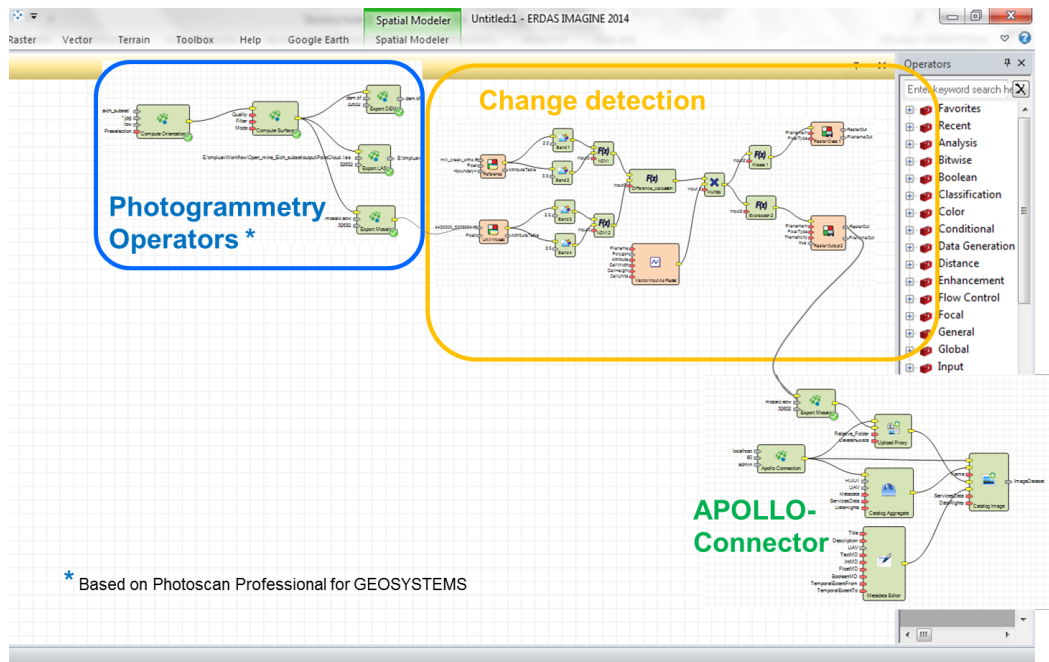
Standard output is an orthophoto mosaic, a point cloud and optional DTM.



Automated generated orthomosaic
of AIBOT images



Automated generated point cloud of Aibot images



Smart combination of UAV operators, change detection and APOLLO connectors within the Spatial Modeler

From a producer's point of view, this highly customizable combination of UAV-photogrammetry, change detection and cataloguing into APOLLO via Spatial Modeler functions is tremendously powerful, saving time, effort, and money.

From a user's perspective, this processing chain runs fully automated with only minimal input. After completion, the results are available or disseminated in many formats like standard OGC web-services or as streaming ECW data.

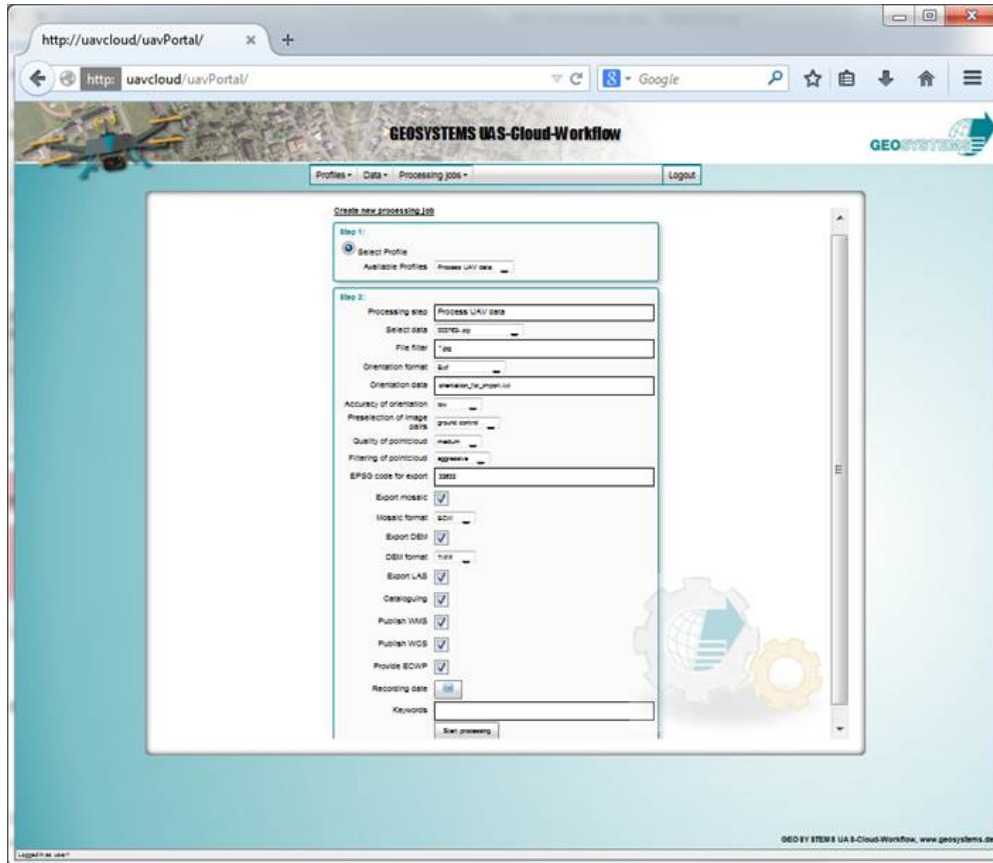
Cloud UAV Workflow

In addition to the Universal UAV workflow, this flavor provides a dedicated UAV data upload portal for the UAV customer. This powerful extension of the universal workflow enables GEOSYSTEMS to host the data via the cloud for data processing and dissemination.



- This version allows for the fully-automated processing of UAV Data on a cloud
- Private cloud
- Public cloud (Amazon/Azure/others)

- Upload portal for UAV data
- Customer credentials for secure access
- Customer profile for order management
- Customer-specified metadata
- Customizable for specific customer needs
- Runs fully automatically



The screenshot shows a web browser window with the URL <http://uavcloud/uavPortal/>. The page title is "GEOSYSTEMS UAS-Cloud-Workflow". The interface includes a navigation bar with "Profiles", "Data", and "Processing jobs" tabs, and a "Logout" button. The main content area is titled "Create new processing job" and contains two steps:

Step 1:

- Select Profile:

Step 2:

- Processing site:
- Select data:
- File filter:
- Orientation format:
- Orientation data:
- Accuracy of orientation:
- Preservation of image data:
- Quality of pointcloud:
- Filtering of pointcloud:
- EPSG code for export:
- Export mosaic: ☒
- Mosaic format:
- Export DEM: ☒
- DEM format:
- Export LAS: ☒
- Orthorectify: ☒
- Publish WMS: ☒
- Publish WCS: ☒
- Provide SCOP: ☒
- Recording data:
- Keywords:

At the bottom right of the form is a "Start processing" button. The footer of the page reads "DEVELOPED BY GEOSYSTEMS UAS-Cloud-Workflow, www.geosystems.de".

Order administration of an UAV data processing order

Near real-time workflow

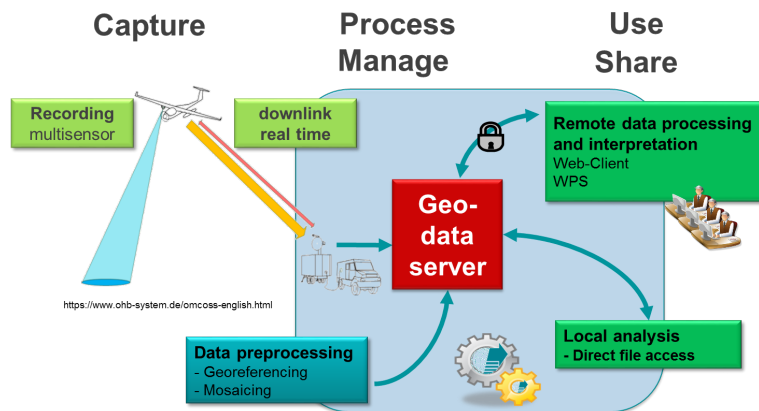
For certain UAS configurations, this workflow can work in near-real-time, providing time-critical, highly-topical information from UAV images for applications such as disaster dispatch centers.

In order to accomplish this, a UAS with real-time downlink equipment is required. This workflow is recommended for surveillance of time-critical situations, like mass events, disaster monitoring, precision agriculture, surveying and bridge inspection.

With an ideal constellation, we can achieve a process rate of 1 sec per image from data capture to web service.

The OHB [Aerial Reconnaissance Data System](#) (ARDS) transmits data directly to the ground station. Due to the excellent flight conditions as well as a very high quality IMU, only basic photogrammetry needs to be applied. Because of the nature of this project, this workflow focuses more on processing speed than on survey accuracy. The UAV Workflow Manager instantly consumes the incoming data and applies all relevant data processing steps, including cataloguing the data into ERDAS APOLLO.

Both the processing speed and the accuracy of the results are startlingly convincing, especially for time-critical applications.



Configuration of the near real-time processing. Part of the German Selsas_Hym Project
 (WTD 81, OHB Systems, Fraunhofer IOSB, GEOSYSTEMS GmbH)



Accuracy comparison of near real-time processed UAV images and Google

Summary

From UAV imagery to universal exploitation, this modular UAS workflow provides powerful, simple and accurate solutions that everyone can use. Utilizing hardware and software components from Hexagon technology, this GEOSYSTEMS workflow is a resounding testament to the power within the Hexagon portfolio.

It is difficult to account for all scenarios when working with UAV imagery. Problems with imagery or hardware are commonplace and invariably slow the workflow down unless you have access to the right tools for all the jobs. Tools like project and imagery importers, distributed batch or conversion processing, and even the often-overlooked support for an enormous collection of projections must be accounted for before all pieces to come together. Even the countless combinations of hardware/software to be used can be overcome through the use of modular and extendable solutions, making it customizable for almost any scenario. Fortunately, the decades of experience in remote sensing and photogrammetry technology at Hexagon Geospatial provides all the answers needed, all contained within one geospatial company.

By integrating the GEOSYSTEMS solution and Hexagon technologies, the perfect UAS workflow can be accomplished from collection to exploitation, either in an IMAGINE viewer or harvested and cataloged by ERDAS APOLLO for the Geospatial Portal end user accessing this imagery over the internet.

About Hexagon Geospatial

Hexagon Geospatial helps you make sense of the dynamically changing world. Known globally as a maker of leading-edge technology, we enable our customers to easily transform their data into actionable information, shortening the lifecycle from the moment of change to action. Hexagon Geospatial provides the software products and platforms to a large variety of customers through direct sales, channel partners, and Hexagon businesses, including the underlying geospatial technology to drive Intergraph® Security, Government & Infrastructure (SG&I) industry solutions. Hexagon Geospatial is a division of Intergraph® Corporation. For more information, visit www.hexagongeospatial.com.

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GEOSYSTEMS is a software vendor offering comprehensive services and consulting with outstanding expertise in remote sensing, photogrammetry, GIS and geospatial data management.

GEOSYSTEMS stands for excellent GeoIT solutions. Due to its first-rate knowledge in the processing of geospatial data, solutions by GEOSYSTEMS ensure that enterprise data and processes are seamlessly integrated with web-based, mobile and desktop clients, following OGC standards and supporting INSPIRE.

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