Understanding Aerial Surveys Through Accessible UAV’s

David Snyder
We've got your back, every step of the way.
Presenter

David Snyder: Solutions Specialist

- Bachelors of Science Degree Louisiana State University 1989
- 26 years production experience in photogrammetry, photo interpretation and GIS mapping projects at management and ownership level.
- Experience in all types of photogrammetry projects including forestry, coastal environments, industrial sites, litigation/expert testimony, utilities, etc.
- 2005, began work with InphoUSA a subsidiary of Inpho. Eight years in various roles with Trimble including regional operations manager, sales representative, support representative, technical sales support representative.
- 2013 role with Trimble change to also include Unmanned Aerial Systems including Trimble UX5 and terrestrial photogrammetric products.
- 2014 expansion into Trimble’s full Geospatial products with the title of Applied Geospatial Expert.
Outline

1. Aerial Photogrammetric History and base for UAV surveys: 10 min

2. Components of UAV/UAS: 30 min
   - UAV
   - Cameras
   - Pitfalls

3. FAA Requirements: 20
   - Last but most important.
What is Photogrammetry?

- The science of making reliable measurements from photographs (aerial and satellite based)

The Problem?

- Aerial images are not maps in raw form. Aerial images must be corrected for location, orientation, distortions and terrain displacement. Many images must be made to look like one image.
19th Century Aerial Imaging Begins

- Aerial photography was first practiced by the French photographer and balloonist Gaspard-Félix Tournachon, known as “Nadar” in 1858 over Paris.
Aerial Imaging Begins

- WW1, the basics of aerial imaging established
Measurements

- **Single Image Measurements**
  - Shadow Measurements
    - Object Height = Shadow Length \( \times \tan (H_c) \)

- **Overlapping Image Measurements**
  - Parallax Measurements
    - Parallax Bar and
    - Float the Dot
**Scale**

- **Image Scale**
  - \( \frac{F}{H} = \frac{DE}{AB} \)

- Focal Length = 6”
- Altitude = 2,000’
- RF = 1:4,000
- Scale 1” = 333.33’
Scale vs Resolution

Highest Resolution?
Largest Scale?
Resolution

- **Image Resolution**
  - Ground Sample Distance (GSD) = smallest light sensing cell ground distance or cell size x image scale
  
  \[ P = PG \]

  \[ \text{GSD} = P \times \text{Scale} \]

  \[ P = 12 \text{ microns} \]

  \[ 1” = 333.33’ \]

  \[ 0.0005” \text{ GSD} \]

  \[ \text{GSD} = 0.17’ \]
Problems to overcome

- Inconsistent Scale
  - Off Nadir images have different scale
Solution

- Inconsistent Scale
  - Reproduce Orientation
  - Orthorectification
  - DTM
  - IMU
  - Aerial Triangulation
Multi Photo Use

- How do we measure across multiple photos?
  - Stereo Pair Mapping
  - Ground Control Needed
  - Ground Control is Expensive
Multi Photo Use

- Aerial Triangulation
  - Tie photos together to reduce GCP’s
  - Pug Marking
Multi Photo Use

- Aerial Triangulation
  - Autocorrelation
  - Block Adjustment RMS
Multi Photo Use

- Aerial Triangulation
Looking down – Nadir image approach
Digital Solution

- Allows
  - *True Orthorectification = Orthorectification of Structures*
  - Camera Distortion
Create Digital Surface Models
Create Point Clouds
Create Surface
Create Contours
Create Orthomosaics
An unmanned aerial vehicle (UAV), commonly known as a drone, is an aircraft without a human pilot on board. Its flight is controlled either autonomously by computers in the vehicle, or under the remote control of a pilot on the ground or in another vehicle.

The term unmanned aircraft system (UAS) emphasizes the importance of other elements beyond an aircraft itself. A typical UAS consists of the:

- unmanned aircraft (UAV)
- control system, such as Ground Control Station (GCS)
- control link, a specialized datalink
- other related support equipment.

Credit: Wikipedia.org
UAV’s come in all sizes
Aerial Imaging Rover

- **Airframe**
  - Internal carbon frame
  - Expanded polypropylene foam body
  - Engine & propeller
  - Servo-controlled elevons

- **Payload Bay**
  - Battery
  - Camera
  - Tracking beacon

- **eBox**
  - GPS & orientation sensors
  - 2.4 GHz radio
  - Autopilot
Airframe

- Internal carbon frame
- Expanded polypropylene foam
- Impact resistant plastics
  - Motor assembly
  - eBox
  - Servos
- Composite fiber parts
  - Elevons
  - Vertical winglets
  - Belly plate
UX5 Payload Bay

- Tracking Beacon Clamp
- Battery
- Camera
Defining the Flight
Planned photos
Timed Photos
Ground Station

- Rugged Tablet
- Flight Planning & Control Software
- Communications Link
- Download Connector
Safety Maneuvers

- **Land**
  - Instruct aircraft to follow land circuit before flight path is finished

- **Fly To**
  - Fly to a user-specified location on map and circle

- **Hold**
  - Circle at current position

- **Here**
  - Fly to location of pilot/GCS and circle

- **Right**
  - Fly 300 m to the right of current heading and circle

- **FTS (Flight Termination System)**
  - Abort flight immediately and spiral downward

- **Up (not shown)**
  - Instruct UA to increase altitude by 10 m
  - Available once a flight maneuver is enacted

- **Down (not shown)**
  - Instruct UA to decrease altitude by 10 m
  - Available once a flight maneuver is enacted
Flight Conditions and Effects

- Result from photo flight

**Ideal**

**Crab**

**Drift**

**Norm**
Flight Conditions and Effects

- Perfect
Flight Conditions and Effects

- CRAB
Flight Conditions and Effects

- DRIFT
Flight Conditions and Effects

- Common
Unstable Flight = … “dancing in the air”

overlap reduction and data gaps

areas with reduced geospatial accuracy
Launch Methods:
Flight Movie

- Launch Movie Andes
- Launch Slow Motion
- Launch Hand Thrown
- Launch Copter

- Landing Movie MacchuPichu
- Landing eBee
- Landing High Winds
- Landing Antiqua
2. Cameras
Light Receptors (sensor)

- **Film**
  - Grain
  - Speed

[Diagram showing ASA 100, ASA 200, and ASA 400 with different grain densities]
Light Receptors (sensor)

- **Sensors**
  - Charged Couple Device (CCD)
  - Complimentary Metal Oxide Semiconductor (CMOS)
    - RGBG
    - CMYG

R+G+B = Pixel Color
Chip Sensors

Nicon 1J
13.2 x 8.8 [mm]

Ricoh GR
7.44 x 5.58 [mm]

Sony A7R
35.9 x 24.0 [mm]

Pixel Size

Nicon 1J
3.4 μm

Ricoh GR
2.0 μm

Sony A7R
4.9 μm
Camera Distortion Calibration

- Calibration require Camera Stability
  - Lens Distortion
  - Platten Distortion
Lens Instability
Camera not optimized = 
... zoom lens, no immobilized lens and autofocus

- Tree branches and terrain in focus

- No stable interior geometry

Higher Flight

Tree branches in focus, terrain slightly out of focus

Lower Flight

Autofocus blurs part of the scene and reduces quality

Lack of stable geometry reduces overall project accuracy
Questions?
6. Fly Legal
Airspace

- Aviators do not see a map the same way we do

- Terrain is a hazard unless it is a runway
  - Controlled Flight Into Terrain (CFIT)

- Map detail is a distraction unless it’s a landmark usable for navigation
Airspace

- Aviation maps show areas of air traffic
  - Represent cylinders/cones of controlled access

- Areas near airports are more restrictive
  - The larger the airport, the more traffic and restrictions

- Controlled airspace is where instrument procedures may take place and are priority
  - UAS operations would require additional equipment
  - Operating illegally here is asking for serious trouble

- Class G is the only uncontrolled airspace
  - Easiest airspace to obtain UAS flight approval

- Populated areas are highlighted in yellow and may have an impact on flight approvals
Airspace Classifications

Airspace Classification

- Class A: 18,000' MSL
- Class B
- Class C
- Class D
- Class E

Airspace Handbook
Manned aviation aircraft have type certificates and type ratings

UAS aircraft classifications are not developed like manned aircraft

FAA defines “small unmanned aircraft” (SUA) as those less than 55 pounds

Not all aviation authorities agree on this definition
  - e.g. France = 2kg
7 Different Pilot Licenses (Defined in Code of Federal Regulation, Title 14, Part 61)

- Student Pilot – “learner’s permit”
- Recreational & Sport Pilot – aircraft, passenger, airspace and environmental restrictions
- Private Pilot (PPL) – personal aircraft operation
  - Instrument rating requires at least PPL
- Commercial Pilot (CPL) – “for-hire” aircraft operation
- Airline Transport Pilot (ATP) – Delta, United, FedEx…
- Flight Instructors (CFI & CFII) – “certified trainers”
Key Differences of Pilot Licenses

- **PPL cannot operate for compensation or hire**
  - Some exceptions, but primarily a recreational pilot
  - Only requires 3rd Class Medical

- **CPL can operate for compensation or hire**
  - Instrument rating not required
  - Requires 2nd Class Medical

- **ATP requires 1500 hours of flight time**
  - Airliner pilots
  - Requires 1st Class Medical
What is Needed for Legal Flight Operations

- 333 Exemption
- Registration
- Certificate of Authorization
- Flight Actions
What is a 333 Exemption?

- A waiver predicated on the **Airworthiness** of the proposed system. The request should include wording that describes:
  - How will the flights be conducted to ensure safe operation
  - Design of the platform
  - Provide manuals
  - Procedures
  - Radio Frequencies
  - System Training
The 333 Exemption Process

- FAA Account is created
  - Receive an FAA### for exemption
  - Process can take several weeks

- Exemption Approved
  - Receive documentation of exemption
  - Receive a “Blanket COA”
Due to the high volume of Section 333 petitions received, we are experiencing delays in processing petitions. We will do our best to process petitions posted to the docket as soon as possible, and in the order they were received. We appreciate your patience as we work diligently to process your requests.

<table>
<thead>
<tr>
<th>Petitions Granted</th>
<th>Petitions Closed</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,662</td>
<td>399</td>
</tr>
</tbody>
</table>

As of 3/01/2016

By law, any aircraft operation in the national airspace requires a certificated registered aircraft, a licensed pilot, and operational approval. Section FAA Modernization and Reform Act of 2012 (FMRA) (PDF) grants the Transportation authority to determine whether an airworthiness certificate is required for a UAS to operate safely in the National Airspace System.
Has someone filed for 333 Exemption

Filter Results By...

Comment Period
- Open (0)
- Closed

Document Type
- Notice
- Proposed Rule
- Rule
- Supporting & Related Material (18)
- Other
- Public Submission (20)

Posted
- Search All

Results per page: 25

JESCO Environmental & Geotechnical Services, Inc. - Exemption/Rulemaking
- Attachment Title: JESCO Environmental & Geotechnical Services, Inc. - Exemption/Rulemaking
- Other by FAA on 11/25/2015
- ID: FAA-2015-6807-0001

Sales at Less Than Fair Value; Final Determinations: Certain Oil Country Tubular Goods from Saudi Arabia
- Document Contents: ...we made changes to the margin calculation for Jubail Energy Services Company (JESCO). Because the revised margi
- Notice by ITA on 08/19/2014
- ID: ITA_FRDOC_0001-1409

state submission 8-16-13
- Proposed Rule by EPA on 01/14/2016
- ID: EPA-R07-OAR-2015-0587-0003

Sales at Less Than Fair Value: Certain Oil Country Tubular Goods from Saudi Arabia
- Document Contents: ...and April, 2014, we verified the sales and cost information submitted by JESCO for use in our final determination. We u
- Notice by ITA on 07/18/2014
- ID: ITA_FRDOC_0001-1343
333 Exemption Online Info

Petition Links with Guides

Has someone filed for 333 Exemption

Example Petition and Information
Registration of UAV

- Is a recent FAA requirement
  - Dec. 21, 2015,

- Why do I need to register?
  - “Must be traceable in the event of an incident”

- Registration is $5

- Deadline to registers
  - February 19, 2016 for systems prior implementation
Registration of UAV

- What is a “Pink Slip”?
  - Is a 90 day temporary waiver while registration is being reviewed.

- What if I don’t register?
  - The FAA may assess civil penalties up to $27,500. Criminal penalties include fines of up to $250,000 and/or imprisonment for up to three years.

- [https://www.faa.gov/uas/registration/faqs/#cov](https://www.faa.gov/uas/registration/faqs/#cov)
Registration of UAV

General

Q1. Why do I need to register?
A. Federal law requires aircraft registration. Registration helps us ensure safety – for you, others on the ground, and manned aircraft. UAS pose new security and privacy challenges and must be traceable in the event of an incident. It will also help enable the return of your UAS should it be lost.

Q2. Does it cost anything to register?
A. Federal law requires owners to pay $5 to register their aircraft.

Q3. What if I have a problem or issue registering my drone?
A. Email us your UAS support questions or inquiries at UAShelp@faa.gov. Live phone support is available from 7 am to midnight Eastern, seven days a week. Phone assistance is available at (877) 396-4636.

Q4. What is the definition of a UAS? Is it different from a drone?
A. A UAS is an unmanned aircraft system. A drone and a UAS are the same for registration purposes.

Q5. Do I have to register my UAS immediately? Is there a grace period?
A. All small unmanned aircraft that meet the registration criteria must be registered prior to operation outdoors. If you operated your small unmanned aircraft UAS before Dec. 21, 2015, the FAA provided a grace period during which you were permitted to continue operations without registering the aircraft. However, beginning February 19, 2016, all small unmanned aircraft owners must register their aircraft if they wish to continue to operate outdoors.

Q6. Does the FAA have the authority to require registration of UAS used by modelers and hobbyists?
A. Yes. By statute all aircraft are required to register. Congress has defined "aircraft" to include UAS, regardless of whether they are operated by modelers and hobbyists.

Q7. What is the penalty for failing to register?
A. Failure to register an aircraft may result in regulatory and criminal sanctions. The FAA may assess civil penalties up to $27,500. Criminal penalties include fines of up to $250,000 and/or imprisonment for up to three years.

Q8. Will an operator be required to have proof of registration while operating the UAS?
A. Yes. You will be required to have your FAA registration certificate in your possession when operating your unmanned aircraft.

Q9. Does the FAA have two different registration systems? If so, why?
A. Yes, there are two systems. The online system is currently only required for UAS used for hobby or recreational purposes. This new registration process is quick and easy and provides the registrant with a registration certificate immediately. The paper-based system is for manned aircraft and unmanned aircraft that are not solely used for non-hobby or recreational purposes or weigh more than 55 lbs. This process takes much longer to complete and the $5 registration fee is non-refundable. The FAA will transition the paper-based system to a web-based tool later in 2016.

Q10. Where can I find information about operating my UAS safely?
A. You can find safety and operating guidance on the internet at www.faa.gov/_uas/model_aircraft. The unmanned aircraft systems website contains important safety guidance as well as other facts and information.

Q11. Are non-U.S. citizens visiting the United States on vacation or for drone competitions required to register?
A. Everyone, including foreign nationals and tourists, who operate a UAS for hobby or recreational purposes outdoors in the U.S. must use the FAA's online registration system. These non-U.S. citizens or non-permanent U.S. residents will receive the same registration certificate as U.S. Citizens or permanent U.S. residents. However, this certificate will function as a "recognition of ownership" document. This document is required by the Department of Transportation for foreign nationals to operate legally in the US.
Certificate of Waiver or Authorization

- **Airspace**
  - Controlled or uncontrolled airspace, but not class B
  - Determined by agreement among Flight Standards and Air Traffic Control

- **Aircraft**
  - Must be owned by the proponent and registered with FAA (N number)
  - Airworthiness of aircraft is self-certified by proponent

- **Operator**
  - PPL Ground school passing grade for Class G airspace
  - PPL for controlled airspace (other than G)
  - Observer and Pilot must each have a current 2nd Class Medical Certificate of Waiver or Authorization
Certificate of Waiver or Authorization

- COA Example
Certificate of Waiver or Authorization

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
CERTIFICATE OF WAIVER OR AUTHORIZATION

ISSUED TO
Any Operator with a valid Section 333 Grant of Exemption

This certificate is issued for the operations specifically described hereinafter. No person shall conduct any operation pursuant to the authority of this certificate except in accordance with the standard and special provisions contained in this certificate, and such other requirements of the Federal Aviation Regulations not specifically waived by this certificate.

OPERATIONS AUTHORIZED
Operation of Unmanned Aircraft Systems in accordance with the operators’ Section 333 Grant of Exemption at or below 200 feet Above Ground Level (AGL) in the National Airspace System (NAS).

LIST OF WAIVED REGULATIONS BY SECTION AND TITLE
N/A

STANDARD PROVISIONS
1. A copy of the application made for this certificate shall be attached and become a part hereof.
2. This certificate shall be presented for inspection upon the request of any authorized representative of the Federal Aviation Administration, or of any State or municipal official charged with the duty of enforcing local laws or regulations.
# Certificate of Waiver or Authorization

**Issued To:**
Trimble Navigation, Ltd, FMRA Section 333 Exemption #11110 as Amended by #11110A

10368 Westmoor Drive
Westminster, CO 0021

This certificate is issued for the operations specifically described hereinafter. No person shall conduct any operation pursuant to the authority of this certificate except in accordance with the standard and special provisions contained in this certificate, and such other requirements of the Federal Aviation Regulations not specifically waived by this certificate.

## Operations Authorized

Operation of the UX5 and UX5 hp Unmanned Aircraft System (UAS) at or below 400 feet Above Ground Level (AGL) in Class G airspace in the vicinity of Savannah, GA, under the jurisdiction of Savannah Terminal Radar Approach Control (TRACON) for the purpose of aerial data collection. See Attachment 1.

## List of Waived Regulations by Section and Title

N/A

## Standard Provisions

1. A copy of the application made for this certificate shall be attached and become a part hereof.
2. This certificate shall be presented for inspection upon the request of any authorized representative of the Federal Aviation Administration, or of any State or municipal official charged with the duty of enforcing local laws or regulations.
3. The holder of this certificate shall be responsible for the evident observance of the terms and conditions contained herein.
What is Needed When you are Ready to Fly?

- **Registration:**
  - The FAA Registration number or “N” number must be clearly written on the UAV
  - You should keep a copy with you

- **Certificate of Authorization**
  - Make Sure to have a copy with you.
  - It provides Instructions require for flight in the waiver area.
Misconceptions Commonly Heard:

- Stay under 400 feet and you don’t have to worry about all this.
  - FAA clearly states that you must follow rules or potentially face FINES

- Send the plane off, and don’t worry about seeing it. It will come back and land when finished.
  - Not an instrument rated aircraft.
  - VFR apply, and you must see the aircraft at all times
Violations and Penalties:

- **Failure to register:**
  - Criminal penalties include fines of up to $250,000 and/or imprisonment for up to three years.

- **Operation without a COA:**
  - Fines at FAA discretion: [LINK](#)
Violations and Penalties:

- **How will they know?**
  - FAA follows up on ALL reports of aircraft being operated in an unsafe manner and registration is a material matter which will be examined when identified.

- **Enforcement Link**

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**Law Enforcement Engagement with Suspected Unauthorized UAS Operations**

There is evidence of a considerable increase in the unauthorized use of small, inexpensive Unmanned Aircraft Systems (UAS) by individuals and organizations, including companies. While the FAA retains the responsibility for enforcing Federal Aviation Regulations, including those applicable to the use of UAS, the agency also recognizes that state and local Law Enforcement Agencies (LEAs) are often in the best position to deter, detect, immediately investigate, and, as appropriate, pursue enforcement actions to stop unauthorized or unsafe UAS operations. The agency’s Law Enforcement Guidance for Suspected Unauthorized UAS Operations (PDF) is intended to support the partnership between the FAA and LEAs in addressing these activities.
Unmanned aircraft must weigh less than 55 lbs. (25 kg).
- Visual line-of-sight (VLOS) only; the unmanned aircraft must remain within VLOS of the operator or visual observer.
- At all times the small unmanned aircraft must remain close enough to the operator for the operator to be capable of seeing the aircraft with vision unaided by any device other than corrective lenses.
- Small unmanned aircraft may not operate over any persons not directly involved in the operation.
- Daylight-only operations (official sunrise to official sunset, local time).
- Must yield right-of-way to other aircraft, manned or unmanned.
- May use visual observer (VO) but not required.
- First-person view camera cannot satisfy “see-and-avoid” requirement but can be used as long as requirement is satisfied in other ways.
- Maximum airspeed of 100 mph (87 knots).
- Maximum altitude of 500 feet above ground level.
- Minimum weather visibility of 3 miles from control station.
- Operations in Class B, C, D and E airspace are allowed with the required ATC permission.
- Operations in Class G airspace are allowed without ATC permission.
- No person may act as an operator or VO for more than one unmanned aircraft operation at one time.
- No careless or reckless operations.
- Requires preflight inspection by the operator.
- A person may not operate a small unmanned aircraft if he or she knows or has reason to know of any physical or mental condition that would interfere with the safe operation of a small UAS.
- Proposes a microUAS option that would allow operations in Class G airspace, over people not involved in the operation, provided the operator certifies he or she has the requisite aeronautical knowledge to perform the operation.
IMPORTANTLY, Pilot License requirement is *proposed* to be eliminated:

- Pilots of a small UAS would be considered “operators”.
- Operators would be required to:
  - Pass an initial aeronautical knowledge test at an FAA-approved knowledge testing center.
  - Be vetted by the Transportation Security Administration.
  - Obtain an unmanned aircraft operator certificate with a small UAS rating (like existing pilot airman certificates, never expires).
  - Pass a recurrent aeronautical knowledge test every 24 months.
A Good Starting Point

- Navigation Electronics Inc
  - UAS Startup Kit
    - Have been highly successful getting their customer legally flying

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Questions?

END