Infrared Image Processing and CWN Incident Support

UASD Information Sharing Season 2021 Preparation

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Office of Aviation Services
Unmanned Aircraft Systems Division

Target Audience

- UASDt Newcomers
- UASD veterans wanting to understand more about the process.
- “Smarty-pantses” who want to show us how to do it better.

About your Presenter

- Office of Aviation Services (OAS), UAS Division since 2016.
- By way of BLM National Operations Center
  - Learned the UAS ropes with Gil, Bobby, Britta, Stroud, Lance Brady.
- Background in Photogrammetry, Remote Sensing & GIS.
- Teach a couple UAS classes at local university.
- First and only fire operation last year on the Bighorn with Brandt.
- Emergency Management Experience
  - Few hundred flights over Kilauea in 2018.
  - Hurricane Harvey Response in 2016.
- Validate with your experience.

- What is “Thermal IR” and How is it Used for Fire?
- The UASD IR Product Development Flow Model
- UASD Toolbox Resources Review
  - CWN Mapping Flight Plan Construction
  - Transect Planning
  - Principles of Aerial Photography and Fire Mapping
  - FLIR Duo Pro User Guide
- Working Through the FLIR Image Processing Workflow
  - Basics of Processing Fire Imagery
  - A Brief Look at Analytics
- Case Study Examples – Bridger Bighorn Fire June 29, 2020
- Parting Thoughts

Key Points for Today’s Briefing

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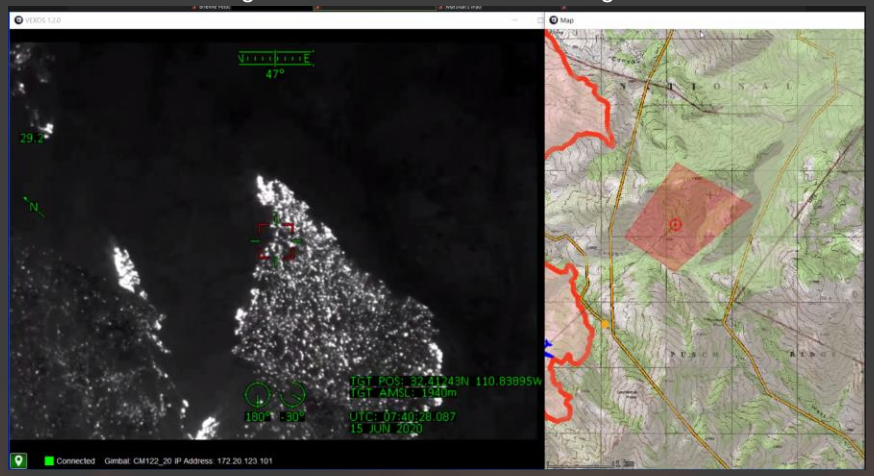
- What is Thermal Infrared Radiation?
  - Energy is present within everything in the universe.
  - Visible light is most familiar form of radiation to us because of our ability to see it reflected off the objects around us.
  - Although our eyes can't see thermal radiation, we certainly can 'sense' it.
  - Electronic sensors are manipulated to detect radiation in the thermal IR region of the electromagnetic spectrum.

Ball sensors offer georeferenced locations making them ideal for ISR.



- How can detected thermal radiation be used to fight fire?
  1. General Intelligence, Surveillance, Reconnaissance (ISR).
  2. Locating spot fires during active fires and mop-up.
  3. Fire Perimeter Mapping.

- Thermal gimbals provide point-based target coordinates.
- FLIR Duo associates a coordinate with the image center, ideal for mapping.

What is Thermal IR Data and Its Uses?

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IR Product Development for CWN Support Overview Model

Site Selection and Flight Planning

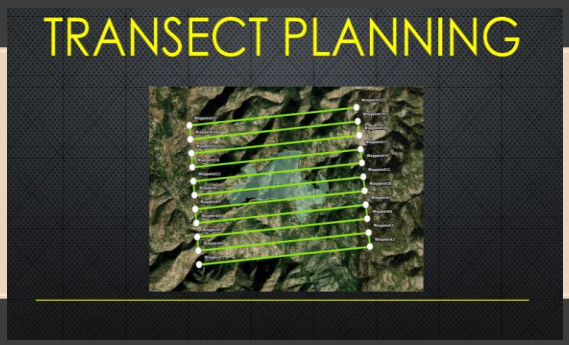


Image Collection and Processing

Product Creation and Delivery

IR Product Development for CWN Support Flow Model

Understanding Stereoscopic Principles

- Stereoscopy allows software to identify common regions among adjacent images (overlap and sidelap). It is the essential ingredient to creating mosaics and 3-Dimensional surfaces from Structure from Motion processes.

Flight Planning

- Prescribed UAS flight paths manipulate flight altitude, speed and transect separation to maintain stereoscopic overlap and sidelap based on sensor focal length and field of view.

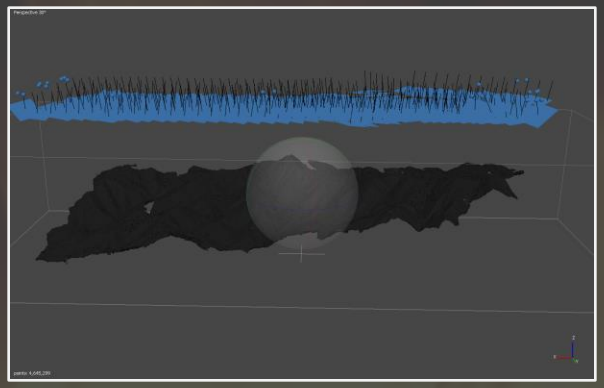
The FLIR Duo has been the sensor of choice among CWN contractors.

Image Collection

- Images are collected as the aircraft travels along the prescribed flight path. The quality, characteristics and quantity of collected images depends on camera settings and triggering mechanism.

Image Selection

- We can select images based on their type, quality and location to increase how fast we can derive products and the quality of the output.



The dense point cloud and originating image locations in Metashape.

Mosaic

- Our job is to deliver image collections with good stereoscopy. Powerful software such as Metashape and Pix4D does the rest by identifying the location of overlapping keypoint pixels.

Product Manipulation

- Photogrammetry is the science of making measurements from photos. Optical imagery means we can measure both space and energy.

Map Products to Support Fire Operations

- Timing, utility and understandability of the final product is essential to keeping our jobs.

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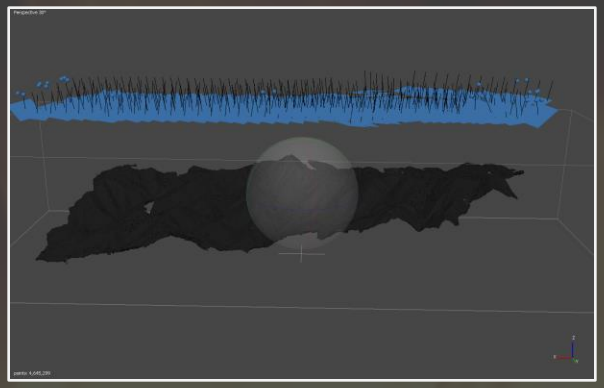

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- What UASD Toolbox Resources are Available? - [UASD Toolbox | BLM UAS Program (nifc.gov)]
  - All the guidance needed to complete the job is available in presentations and documents available on the UASD Toolbox page.
  - However, accumulated knowledge and experience is important given the complex and dynamic nature of data collection.
  - Step-by-step instructions support Agisoft Metashape and ArcGIS.

- What is Missing?
  - A couple tweaks and new tools may improve performance and product quality.
  - ArcGIS support is waning – need support for ArcPro.
  - Pix4D Mapper offers a suitable alternative to Metashape.

Everything in ArcGIS is available in ArcPro…somewhere.
Brandt Hines at the Bighorn fire, June 2020.

UASD Toolbox Resource Review

UASD Toolbox Product	Description	Category	User's Comment
1. CWN Mapping Flight Plan Construction	Very basic flight plan creation using polygons in Mission Planer.	Flight Planning	Not much to this guide and the information is represented elsewhere.
2. Transect Planning	The "How To" for transect planning in MP to Shapefile creation.	Flight Planning	PRIME MATERIAL. This guide is needed to do the job.
3. Principles of Aerial Photography for Fire Mapping	Detailed considerations for flight planning.	Flight Planning	Ideally, the vendor already knows this stuff and is only asking for transects.
4. FLIR Duo Pro R User Guide	How-to for configuring the FLIR Duo.	Camera Function	If you need this guide, the vendor is looking for help.
5. FLIR Vue Pro R Metashape Single Page (USGS)	Quick guide to the full workflow of creating robust 3D datasets.	Image Processing	Typically, more steps than we need to create 2D products desired on most fires.

Table of UASD Toolbox Resource (1/2)

UASD Toolbox Product	Description	Category	User's Comment
6. FLIR Vue Pro R 13mm Orthomosaic Full Workflow for Metashape (USGS)	How to plan and capture FLIR Pro data.	Flight Planning & Processing	More targeted to individual data collection. CWN relevance covered elsewhere.
7. Agisoft Metashape User Guide v1.5	The Agisoft Userguide provides limited insight into tools and commands in Metashape.	Image Processing	Handy to reference but not awesomely descriptive.
8. Basics Processing Fire Imagery	Meat and potatoes of making data products from captured images.	Image Processing	PRIME MATERIAL. This guide is needed to do the job.
9. Manipulating Imagery with ArcGIS	Basics of image display in ArcGIS.	Product Creation	Crucial info for common cartographic tasks.
10. UASD Tools Zipfile	Contains essential tools for completing the mission.	Multiple	CsvToGpx.exe Fire ODS.xlsx Slyderpyscript.docx
11. UASD Python Tool	Tools for enhanced UASD performance.	Multiple	Calc_Site_Selection_Viewshed.py Copy_step_images.py KML to shapefile.py (enhanced Slyderscript).

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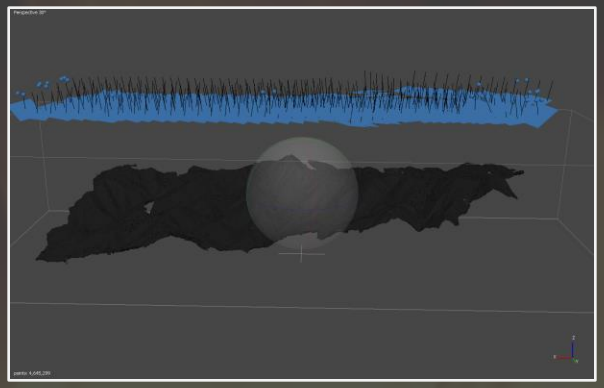

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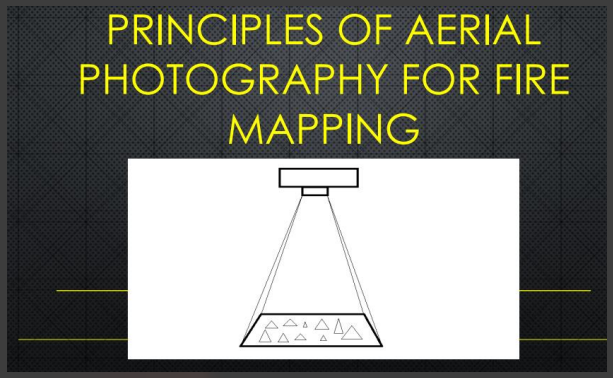
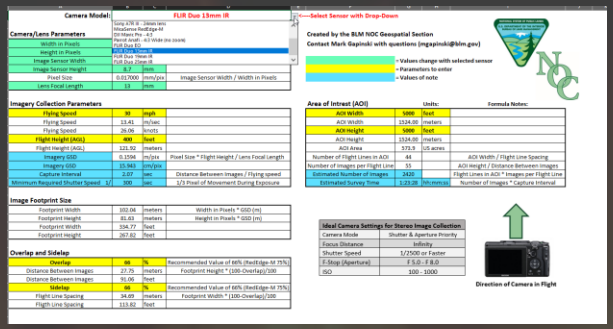
- Stereoscopic images share geographic overlap.
- Stereoscopic overlap is required for adjacent images to be collocated by Metashape.
- We achieve stereoscopy by ensuring adjacent images share overlap and sidelap, expressed as a percent of the total image footprint.
- Overlap is achieved by triggering the camera at a select interval of time or space, in the direction of travel.
- Sidelap is achieved between transect flight paths.
- An “Object-Distance Spreadsheet” provides a overlap and sidelap calculations based on sensor focal length, sensor size, flight altitude.
- USGS National UAS Project Office ODSs.

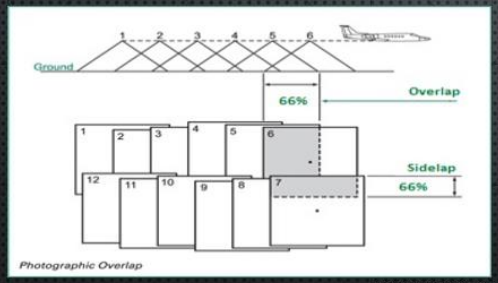




Understanding Stereoscopic Principles

Where is Photogrammetry?

OVERLAP/SIDELAP



Photogrammetry News

- For Photogrammetry software to align photos and have best results we use 66% sidelap and 66% overlap
- This needs to be based on the highest point in the area covered

- Overlap is usually determined using an “Intervalometer” which triggers the camera at set time intervals.
- Distance triggers are less common but eliminate some of the guess work.

- We recommend 85% overlap and 66% sidelap for single-band images.
- 66% is based on 3-band (or more) sensors where more information exists within a single pixel location.
- FLIR output is a single-band image, which is a little more challenging for Metashape to identify keypoints (unique pixel locations).
- Ideally, the vendor will have some recommendations that have proven successful.

Overlap and Sidelap

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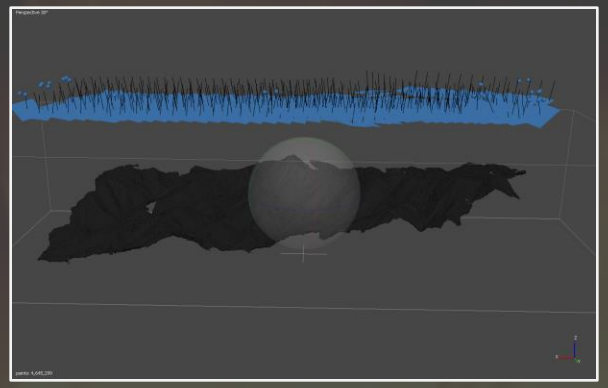

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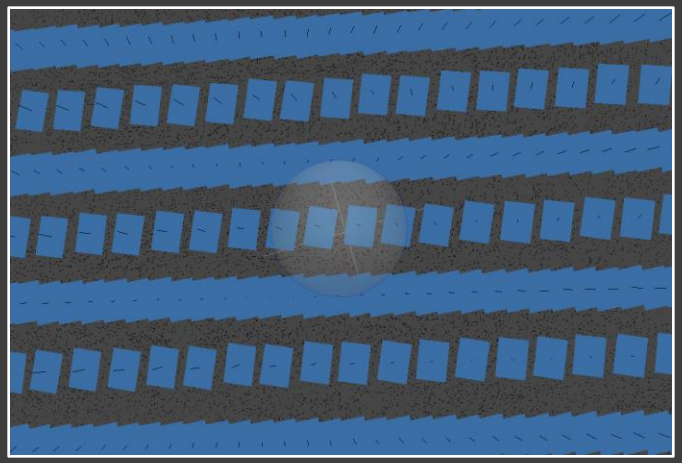
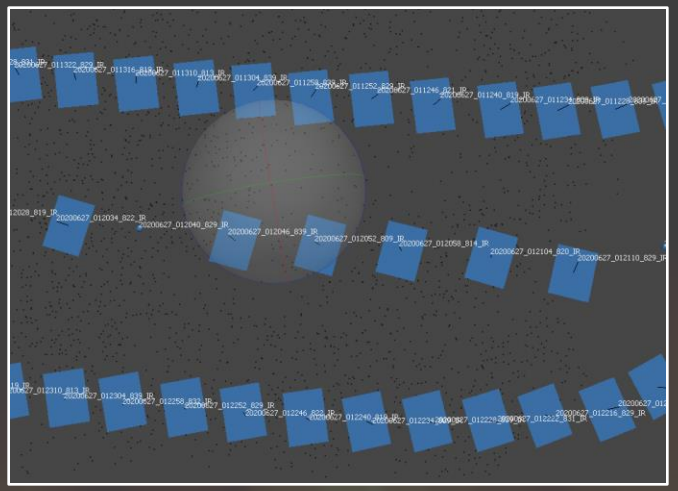
- Select overlap for the available sensor at the highest point in the expected target area at the camera focal length.
  - Max(Target DEM (agl) – Flight Height (agl)) = Flight planning Altitude.
  - Typically, we make a single set of transects to cover the entire target area.
  - This means, if we want stereoscopic overlap over 100% of the target area, in variable terrain, we'll have excessive overlap and sidelap.
  - We haven't talked about selecting the target area, but that can change in the air depending on priorities identified by the IC or by changing environmental and fire conditions.
  - Good coordination between the flight crew and UASD.
  - Good understanding of the terrain in AND AROUND the target area is important.
- Wind direction can have multiple impacts on flight planning.
  - Parallel transects can cause great variation in acquisition location (for intervalometers) – See Image 1 to the right.
    - Very bad if windward travel causes non-stereoscopic gaps between acquisition points.
  - Perpendicular transects can cause crabbing. – See Image 2 to the right.
    - With extreme crabbing, stereoscopy is limited to image corners.
- The FLIR is typically non-gimballed so don't count on fringe images aligning (banked photos).

Flight plans parallel to the wind produces variable overlap.



Flight plans perpendicular to the wind can produce crabbing.



Crabbing reduces the area of image overlap.

Flight Planning

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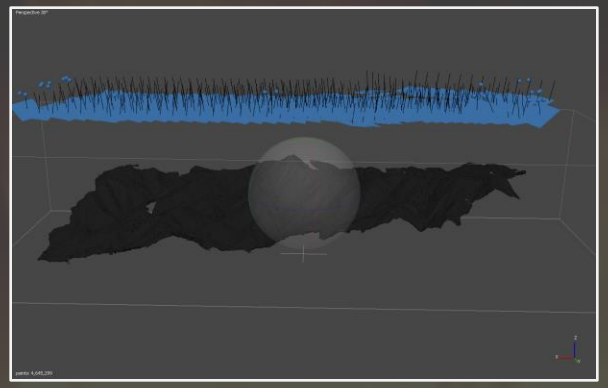

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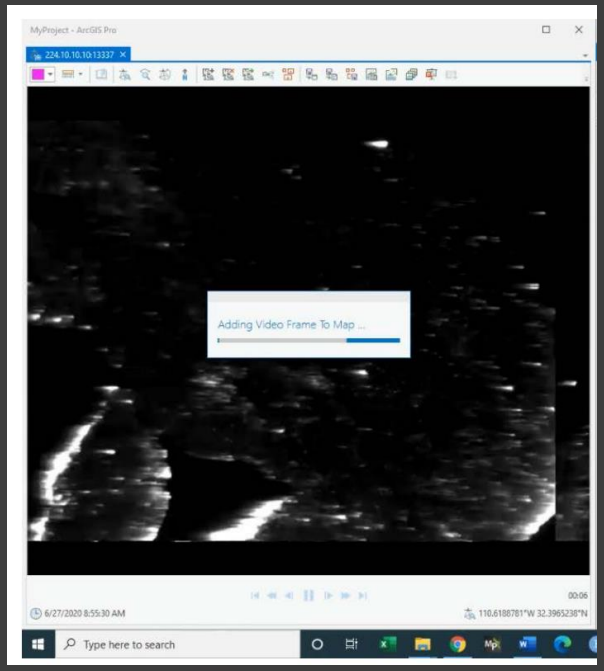
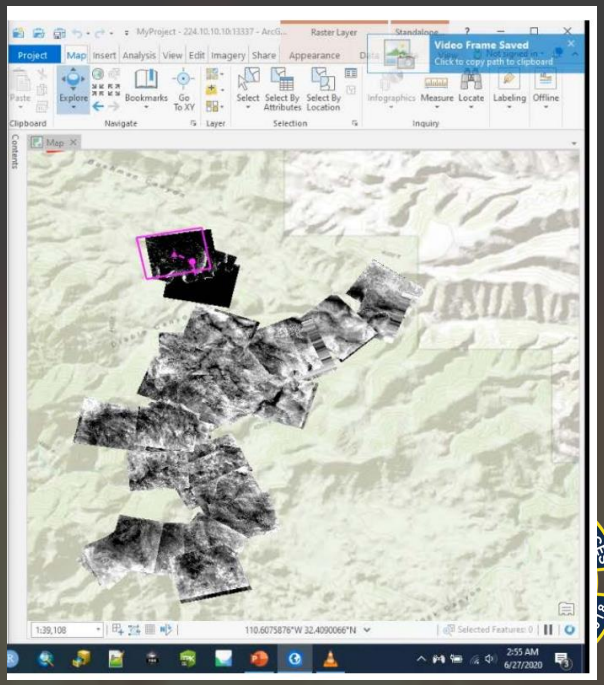
- UAS is doing the work and out of our hands.
- A couple things to consider:
  - It would be great to be able to verify a few things during collection:
    1. Camera is triggering.
    2. Images are geotagged.
    3. Overlap is adequate (unskewed and big enough).
  - Bridger mentioned the ability to either process images onboard or transmit images during flight.
  - Gimballed mapping cameras are going to provide more useful data especially when the mapping mission is hijacked by ISR.
  - Brandt and I experimented with FMV acquisition using the ISR FLIR.
    - Only as good as the geo-information on the ISR sensor.
    - Auto-adjusting histogram made a comprehensive mosaic difficult to achieve.
    - Requires solid and constant feedback between flight crew and UASD (where to look).
    - Ruled out as an effective method for making products.





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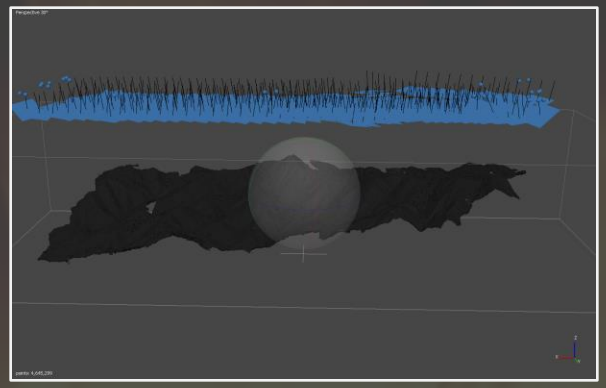

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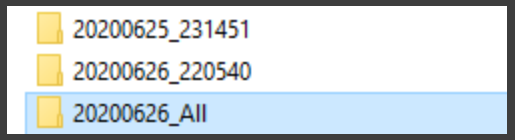
Image Selection

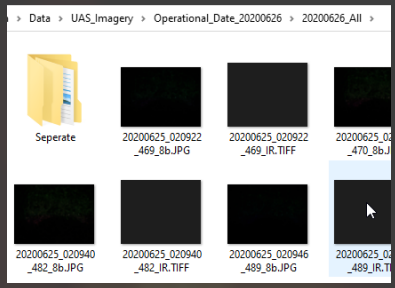
- After the flight, we receive the (or multiple) SD card(s) from the vendor typically with both RGB and IR photos.
  1. Create single folder with images from both cards.
  2. View images
     1. Image Count
     2. Geotag info present
  3. Separate images into RGB and IR folders.
     - See copy_step_images_UASd.py.
     - IR images can be converted to viewable format, but this usually isn't necessary.
     - ImageJ is rudimentary software.
     - IfranView has a few more capabilities.
  4. Select step images for over-collects.
  5. Further reduce processing photos after Alignment in Metashape (take-off and landing, ISR collects).

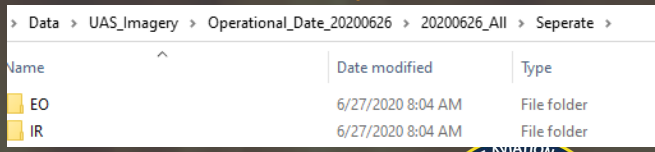

```
########## User Inputs #####
inDir = r"C:\0_Projects\Fire\Bighorn\Data\UAS_Imagery\Operational_D
outDir = os.path.join(inDir, "Separate")

EO_ext = ".JPG"
IR_ext = ".TIFF"

Step =  0 #Step 2 is every other photo, 3 every third photo, etc.
```







IR TIFF
Horizontal Resolution: 17 micrometers @ 512x640
Spectral Resolution: 1 band
Radiometric Resolution: 16 bit (65,000+ total values)

RGB JPEG (Born in the Duo)
Horizontal Resolution: 1.85 micrometers @ 4000 x 3000
Spectral Resolution: 3 band
Radiometric Resolution: 8 bit (256 total values)

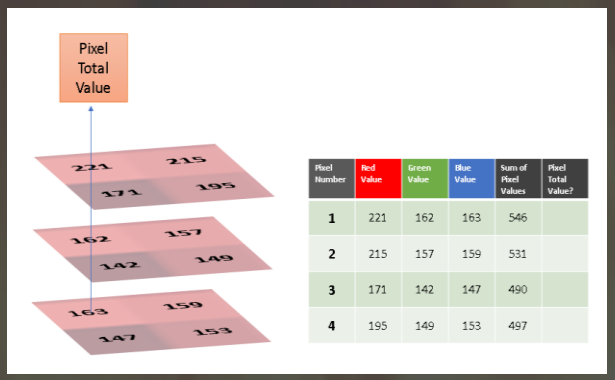
External FLIR Duo Page.

IR JPEG (Converted using ImageJ)
Horizontal Resolution: 17 micrometers @ 512x640
Spectral Resolution: 1 band
Radiometric Resolution: 8 bit (256 total values)

Challenges to IR – Why we need 85%
- Smaller sensor, fewer pixels.
- Single band means fewer statistical uniqueness.

+ TIFFs provide the greatest radiometric resolution.

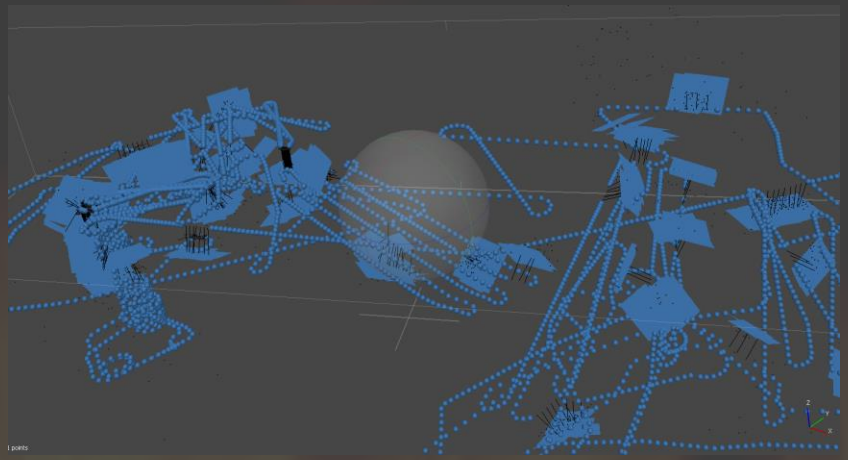
- The vendor is likely to have an idea about what will be effective.



Pixel Number	Red Value	Green Value	Blue Value	Sum of Pixel Values	Pixel Total Value?
1	221	162	163	546	
2	215	157	159	531	
3	171	142	147	490	
4	195	149	153	497	

Thermal IR Image Properties

- Select images in the target area only.
  - Especially huge difference with some ISR.
- Select images that are captured during projected flight conditions.
  - Spiral ups and downs should be eliminated.
- Select level images.
  - The ungimballed FLIR Duo will collect off nadir images when the aircraft is banked.



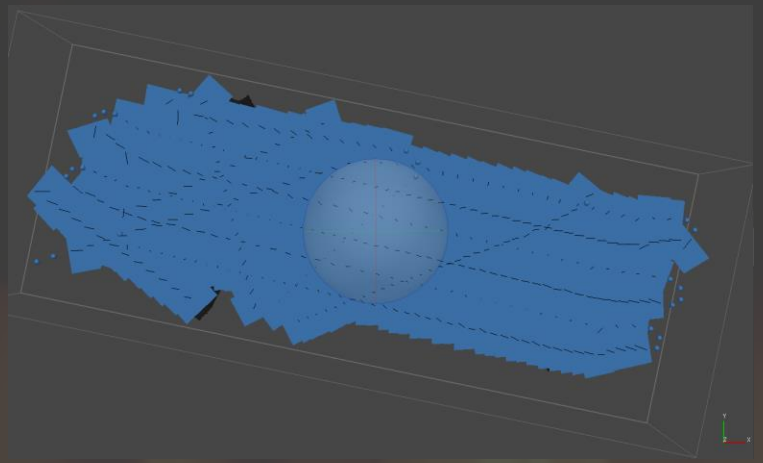


Image Selection by Aircraft Location

IR Product Development for CWN Support Flow Model

Understanding Stereoscopic Principles

- Stereoscopy allows software to identify common regions among adjacent images (overlap and sidelap). It is the essential ingredient to creating mosaics and 3-Dimensional surfaces from Structure from Motion processes.

Flight Planning

- Prescribed UAS flight paths manipulate flight altitude, speed and transect separation to maintain stereoscopic overlap and sidelap based on sensor focal length and field of view.

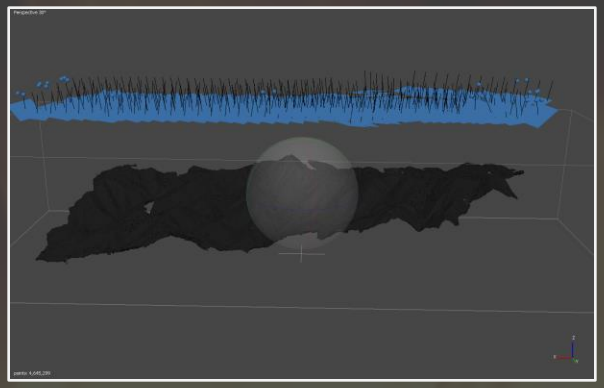
The FLIR Duo has been the sensor of choice among CWN contractors.

Image Collection

- Images are collected as the aircraft travels along the prescribed flight path. The quality, characteristics and quantity of collected images depends on camera settings and triggering mechanism.

Image Selection

- We can select images based on their type, quality and location to increase how fast we can derive products and the quality of the output.



The dense point cloud and originating image locations in Metashape.

Mosaic

- Our job is to deliver image collections with good stereoscopy. Powerful software such as Metashape and Pix4D does the rest by identifying the location of overlapping keypoint pixels.

Product Manipulation

- Photogrammetry is the science of making measurements from photos. Optical imagery means we can measure both space and energy.

Map Products to Support Fire Operations

- Timing, utility and understandability of the final product is essential to keeping our jobs.

1. Follow the guide.

2. Garbage in, garbage out – If you collect good imagery, building products will go well.

3. Typically, RGB images do not add much to alignment (assuming 1) and can severely increase alignment and product development time.

4. Depending on terrain and collection quality, you may be able to use ‘stepped’ images (not all the images).

5. TIFF IR images are going to provide more precision in the alignment process.
   - Not much difference observed between TIFF and JPG alignment.

6. Pix4D Mapper will have similar results but includes some auto calibration.

Mosaic Tips

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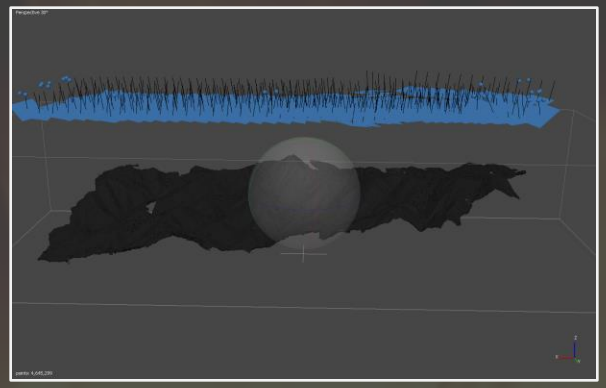

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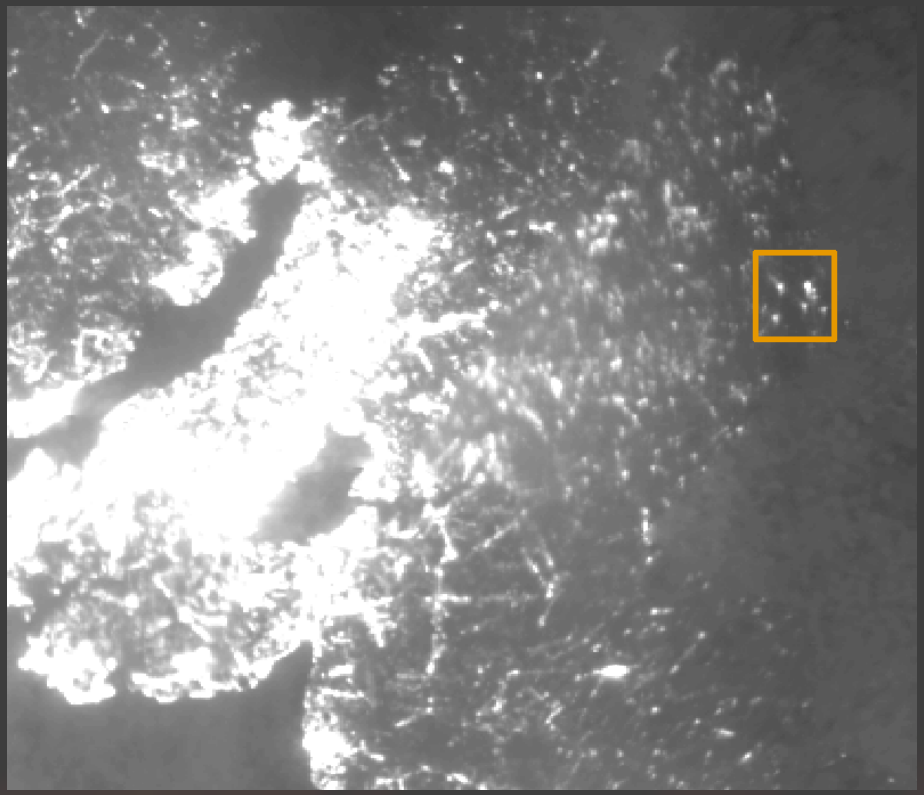

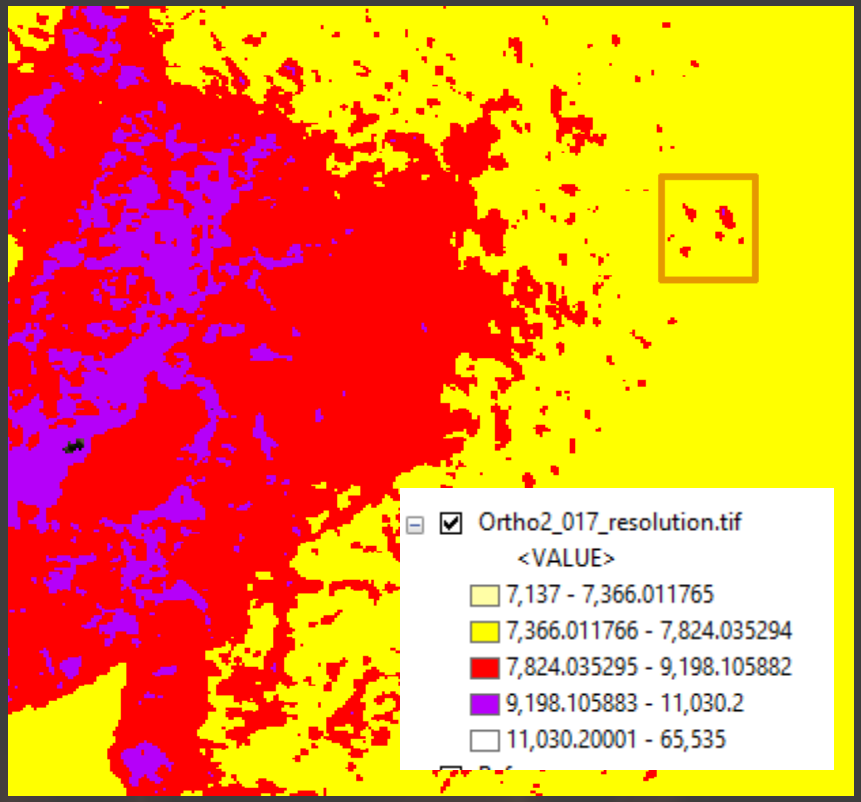

Radiometric values can be used to find areas of heat intensity

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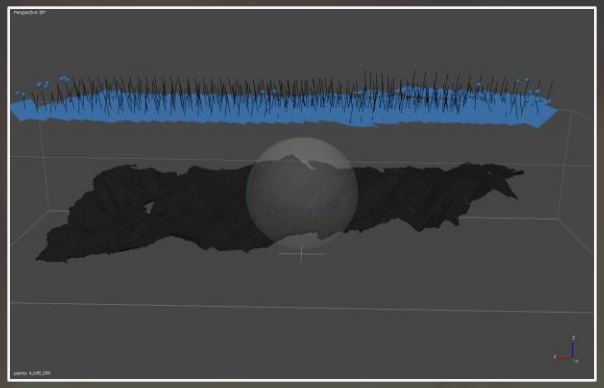

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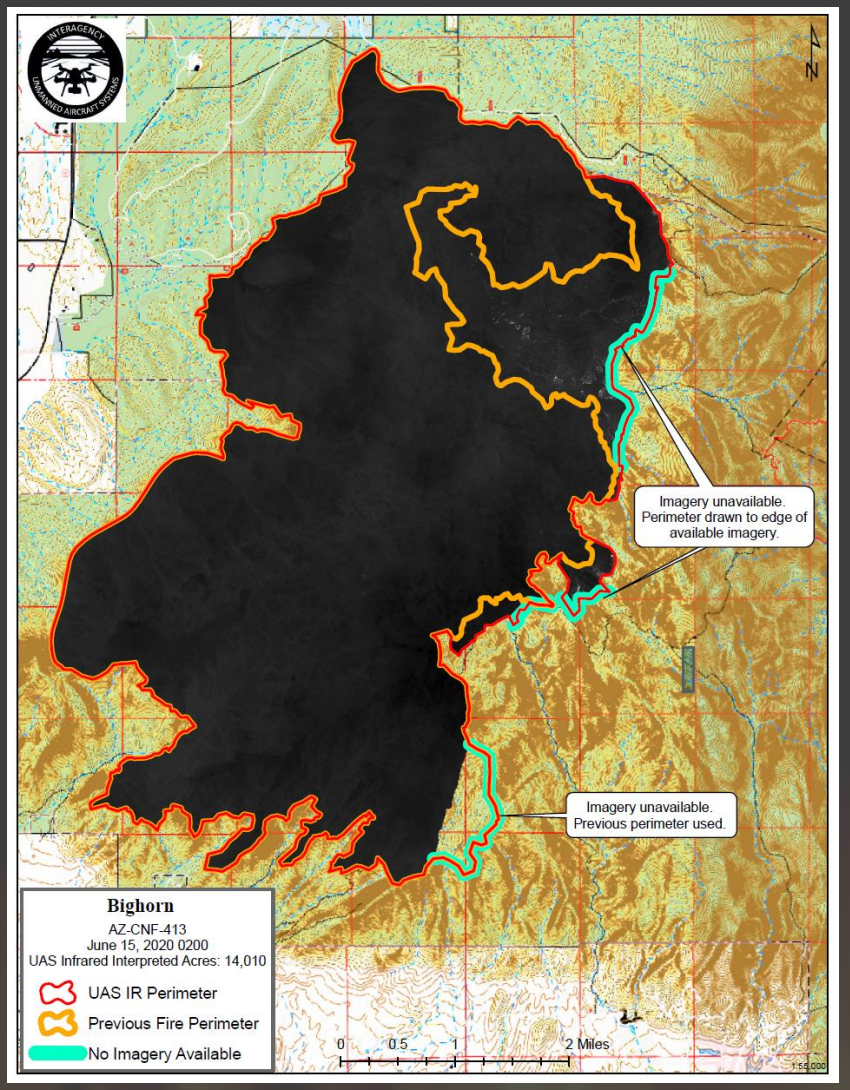
Map Products to Support Fire Operations

- Timing, utility and understandability of the final product is essential to keeping our jobs.

- Utility of UAS data dependent on a few factors:
  1. NIROPS Timing
     - How much burns between NIROPs and the morning brief, and whether UAS operations were mapping in that burned area.
  2. ISR / Mapping Priority.
     - We can get lucky over small areas.
     - Planned transects are not always necessary for stereoscopy.
  3. Size of mapped area.
  4. Preparation race to morning briefing.
     - Image selection
     - Mosaic
     - Map
     - Annotate
     - Deliver for review.



Map Products

- What is “Thermal IR” and How is it Used for Fire?
- The UASD IR Product Development Flow Model
- UASD Toolbox Resources Review
  - CWN Mapping Flight Plan Construction
  - Transect Planning
  - Principles of Aerial Photography and Fire Mapping
  - FLIR Duo Pro User Guide
- Working Through the FLIR Image Processing Workflow
  - Basics of Processing Fire Imagery
  - A Brief Look at Analytics
- Case Study Example – Bridger Bighorn Fire June 29, 2020
- Parting Thoughts

Key Points for Today’s Briefing

- Equipment
  - Big Monitor
  - 3 X memory sticks
  - External drive for recording videos (VLC Recorder)
- Software (non-network computer can be important)
  - VLC Recorder
  - WinTak
  - ImageJ
- Documentation
  - Keep a daily brief describing actions.
  - Take pictures and videos.
    - This is a marketing game as well.
  - Screen recordings.

Parting Thoughts

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- Jay Murgoitio – Thank you for the invite.
- Bobby – Resource gathering and organization.
- My Reviewers
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  - Brandt Hines
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- You

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