Call When Needed UAS Operations
June 6 – July 1, 2020

Vendor: Bridger Aerospace - Latitude

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Sawtooth Fire June 6 - 8, 2020. Daytime operations.

1. **Test flight was conducted.**
   - Outcome: No IR images captured.
   - Takeaway: Conduct test of camera before flight. Capture a few photos to ensure it is functioning.

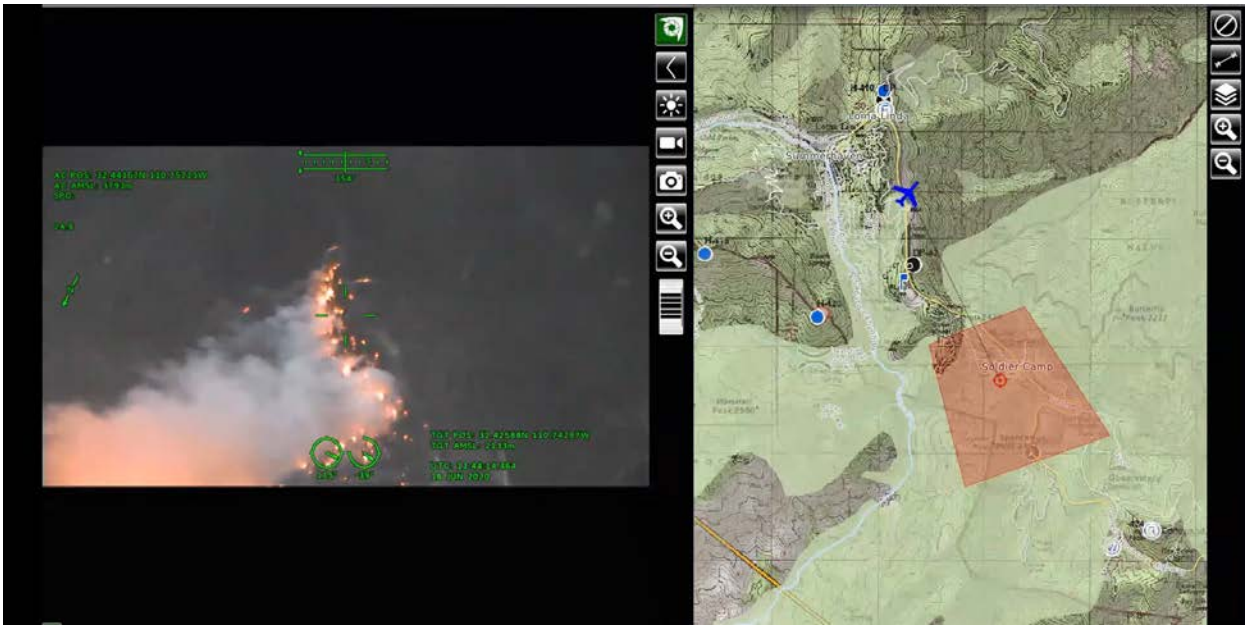
2. **EO flight mapping fire (about 20,000 acres)**
   - Outcome: Vendor had link issues with aircraft causing extended mapping mission delays. FLIR camera photos had no geo-tags.
     - Difficult to develop a product without geotags. Metashape software could create a mesh and then orthophoto but no DEM. Orthophoto had to be developed in sections, otherwise only small areas of photos would align and processing time increased. Orthophoto sections had to be hand georeferenced in ArcGIS which was difficult and time consuming.
   - Takeaway: Incident was impressed with the EO orthophotos resolution and scale despite having holes and gaps where photos wouldn't align in Metashape. Could have flown wider transects and longer time between photo triggers which would have reduced flight time, but not helped geotag issues.
     - It was determined that the GPS signal to the camera became loose. Vendor can check GPS data in flight to help ensure geotags are being collected.
3. **GCS maps**
   - Geotiff, 1200dpi, world file. Everything looks good after export from ArcMap. However, when imported into flight control GCS, black colored features appear transparent (drop points, controlled fire line). Adjusting the color of these features to a lighter tint helped but the issue was never fully resolved.
   - Vexos software (used for gimbal camera and display GCS) wouldn't display geotiff. Vendor had to send the updated map files daily to their engineers in order to get the current map to display in Vexos. The problem was never determined, Vendor is working on a fix. Physical map transfer does inject a modest coordination burden for the UASD.
   - Vexos software is developed in Australia and uses metric measurements requiring on the fly adjustments from meters to feet and kilometers to miles when relaying information to incident personnel.

Bighorn Fire June 9 - July 1, 2020. All night shift operations.

1. **Photos importing into Metashape:**
   - Can use the "search" function in Windows File Explorer for JPG or TIFF to quickly select EO vs IR photos. Minimize the window to show every 2nd, 3rd, 4th, etc, photo and use selection box to highlight and delete if needed. Another option is Rich Thurau's "PhotoSelectionAndReductionPython" script which will also allow you to eliminate photos based on the number you provide (every 2nd, 3rd, 4th, etc.)
   - Camera specs for FLIR IR from manufacturer not accurate when entered into Metashape. This has something to do with the way Metashape reads the EXIF data vs manual inputs. Use the numbers generated by Metashape.

2. **Perimeter mapping**
    - Using IR photos in Metashape:
        - Metashape processing is much quicker (from 1 hour down to 15 minutes depending on number of photos) if just using IR and leaving out all EO collected photos. Alignment, Dense Cloud, etc. will all process much quicker and allow UASD a tighter processing window to provide more up to date products.
    - Get estimated perimeter location from Ops or Sit before each flight.
        - This helps guide where flight transects will need to be collected.
        - Flight transects are adjusted to angle requested by PIC this would normally be based on wind direction (drawn perpendicular to wind direction) or best angle to maintain link with aircraft.
    - Challenges to effective perimeter mapping with Bridger:
        - Contractor crew had limited understanding of photogrammetry and the specific cameras being utilized.
        - UASD created flight transect shapefiles which were uploaded and traced by the crew as waypoints in the Piccolo GCS.
        - Estimating correct width of transects is challenging due to some key factors:
            - The extensive flight time of the aircraft covers a lot of area with varying terrain (i.e. AGL constantly changing).
            - FLIR images include only one band, limiting info used by Metashape to stitch neighboring images – amplifying need for geotags.
            - No real-time feedback means not knowing if data are good until back on the ground.
            - In-flight mapping changes requires air crew to manually draw flight lines.
    - If needing a quicker product, reducing sidelap by half (66% to 33%) and increasing overlap (66% to 80%) will allow greater distance between transects but still usually produce usable photos for IR perimeter.
    - It is important to try and eliminate any off-nadir photos. These are generally created when the aircraft turns as it is flying transects and as aircraft is spiraling up or down in the LRZ. Off-nadir photos make alignment issues and can create gaps in the Metashape processing.
    - Full fire perimeter is limited by time constraints and size of fire:
        - Time required to develop a product (perimeter shapefile and map) after aircraft lands and photos are transferred is about 2 hours if there are no complications and just processing IR.
        - SIT/GISS usually want a product by 0400. This means mapping mission must be completed and on ground by 0200.
        - 25,000 acres was about the max amount that could be mapped based on time constraints. If fire is larger than this, priority areas had to be chosen.
        - Using these methods, there was limited additional value to what was provided by NIROPS because flights were within a few hours of each other.

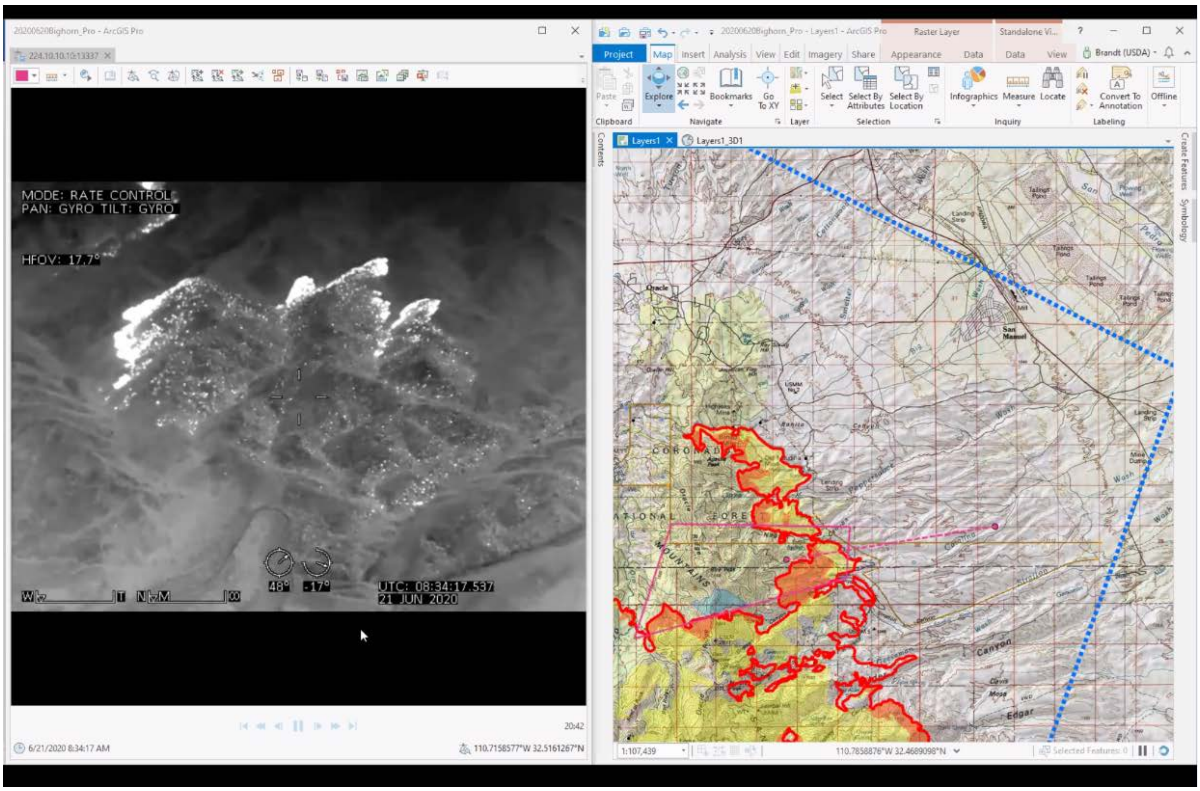
3. **Real-time viewing options for incident personnel SA:**
    - Zoom screenshare with vendor GCS through vendors computer:



        - This process works well if all interested parties (Ops, FBAN, UAS crew, etc.) have a reliable data connection.
        - Set up a recurring Zoom call with a paid account for full flight time coverage (8 hours) and share Meeting ID and Password with anyone who has a need to view video.
        - Vendor is the Zoom call Host and they share their screen showing gimbal Camera view and Vexos Map on split screen (shown above).
            - FirstNet hotspot tested with success and improved data connections vs standard MiFi hotspots. Suggested at least two of these become a standard part of the "UAS Kit" for improved data connections.
            - Kymeta satellite internet tested with success, though similar data quality speeds as cellular hotspots. Main advantage was its use when cellular connections were limited or unavailable.
            - Silvis radio may be another option if lacking a good data connection. It was proposed but never tested.
        - **PROS:**
            - Ops or others can talk through Zoom and make requests directly to UAS pilots.
            - Anyone can have access to real-time video and map location.
        - **CONS:**
            - Requires a good data connection from UAS crew location in order to share Zoom call. Also requires anyone that wants to view video to have a good data connection.
            - Hot mics can be a problem, need to remind participants to mute if not needing to communicate. All communication is shared with everyone on the call.
            - Extra burden/task placed on the UAS pilot/gimbal operator to share screen and monitor Zoom call to allow new participants into the call.
            - Off NADIR geolocation accuracy (or lack of) was not always effective at positively identifying what was being viewed.
        - **FUTURE**
            - If a good data connection can be available this is the recommended version for sharing real-time information.

- A consistent Zoom call account, ID, and password would make sharing call information more efficient.
- Could mirror the vendors screen to another computer and have this computer be the Zoom call host in order to alleviate the burden of permitting participants and managing the call from the pilot and gimbal operator.

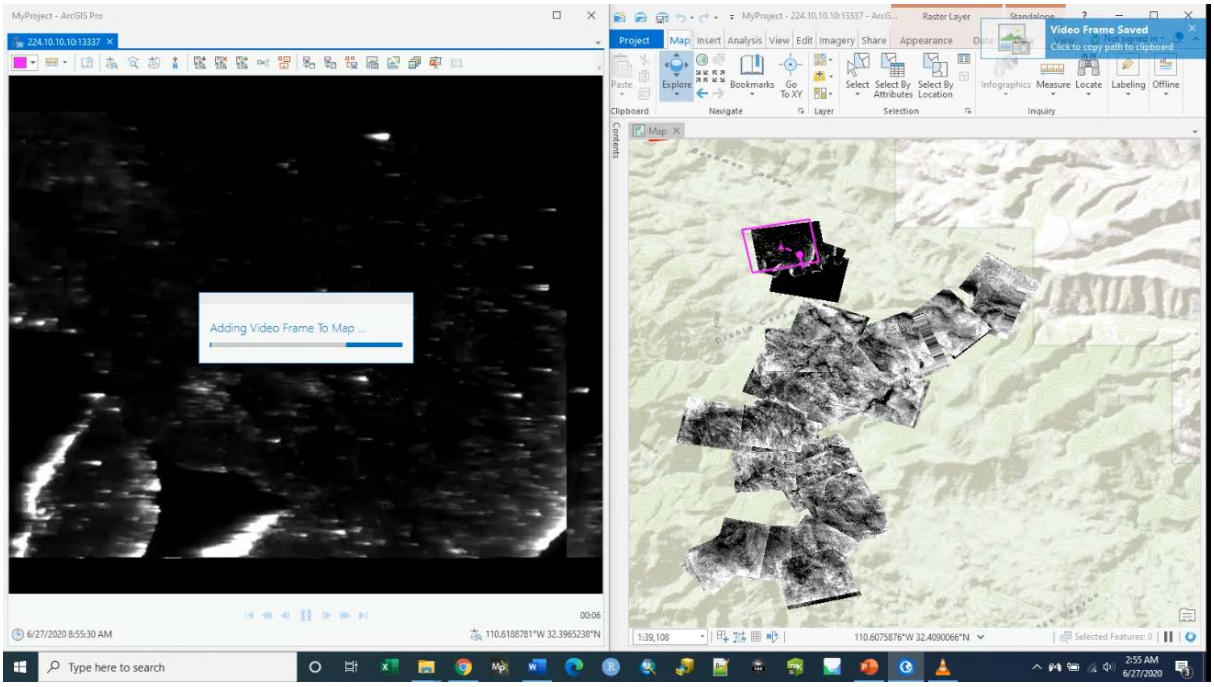
- <u>Zoom screenshare with ArcGIS Pro and FMV through UASD computer</u>:



  - Zoom is set up the same way as discussed above, however the UASD is the host and shares their screen with ArcGIS Pro map on one side and FMV (Full Motion Video) video feed on the other. FMV provided from Vendor via ethernet cable and displayed through ArcGIS Pro (shown above).
  - **PROS**
    - Map is much better quality and you have the full functionality of ArcGIS Pro for real-time mapping and providing SA with the map independent of vendor software.
    - 3D map view in ArcGIS Pro looks great and is more easily understood by users on the ground.
    - Allows UASD to capture georeferenced screen captures from gimbal camera for real time products. (see picture below)
  - **CONS**
    - Licensing of Image Analyst extension in ArcGIS Pro is required to use FMV.
    - Map would randomly crash, especially when using the 3D map. This seemed to improve after updating to the latest version of Pro, but still had inconsistencies.
    - Gimbal camera video wouldn't show full display in EO view, only about half of the screen.
    - Georeferenced screen captures are only as good as the camera data on the UAS provides. Accuracy was greatly reduced the further from nadir the camera was. Trying to keep the camera at nadir made it difficult for pilots to determine where fire edge was. IR gimbal camera adjusts radiometric view based on current frame view, so if there

was not a big difference in hot and cold, it was nearly impossible to determine if we were viewing fire edge or not, as the whole picture would show variations of “heat”.

- **FUTURE**
  - Need to improve gimbal camera accuracy off nadir. Vendor mentioned adjustments are being made to how the camera collects and determines location information.
  - Eliminate ArcPro crashing. Emails and information have been sent to ESRI representatives to hopefully improve performance.
  - IR and EO view need to adjust correctly with FMV feed into ArcPro. Vendor mentioned a new video processor in development for their system that may alleviate this by being able to feed both camera types (IR and EO) to FMV simultaneously.
  - Hopeful for this method, as real-time mapping would be the most beneficial process, but the bugs need worked out and accuracy improved before it can be the recommended option.
  - ArcPro Screen grab of real-time perimeter mapping using “Frame Capture” FMV below:



- <u>WinTAK/ATAK</u>
  - **PROS**
    - Free download and easy to learn user interface.
    - FMV video feed works well and transitions between IR and EO without error.
    - Can be used as an alternative to sharing the vendors screen for real-time viewing.
    - Integrated with many commercial data transmission systems (MANET, Somewear, Beartooth, SPOT, ShoutNano, GoTenna, 5X Systems) to distribute small GIS data (points, lines, polygons) or FMV
  - **CONS**
    - Limited mapping capability, useful for viewing but limited for mapping.
  - **FUTURE**
    - Potential for use with ATAK for people in the field to communicate, but never had the chance to test.
    - Is there value added? Do users in the field need to be able to draw on map and update features or is viewing and verbal communication sufficient.

        - Test WinTAK Photogrammetry plugin for creating map layers with collected imagery from mapping mission

- Google Earth with LineVision
    - Attempted to use trial software "LineVision" from RemoteGeo to view FMV in Google Earth.
    - **PROS**
        - Uses the popular and easy to visualize functionality of Google Earth.
    - **CONS**
        - Poor visual quality and inaccuracies from FMV.
        - Limited mapping capabilities in Google Earth.
    - **FUTURE**
        - Determined not to be a viable option due to limitations.

4. **Lessons Learned Summary**:
    - Checklist to ensure FLIR camera is collecting both TIFF and JPG and has Geotags.
    - Double check TFR before flight and especially after adjustments to TFR have been made to ensure times, LRZ locations, elevations, etc. are still valid. See Safecom filed: https://www.safecom.gov/safecom/20-0279
    - Anticipate fire growth and how to expand flight transects if needed.
        - Get an estimated fire perimeter location from Ops or SIT before mission.
        - Perform a pre-transect flight to determine perimeter and where to create transects. This will help mapping flight be more productive and accurate.
    - Good communication is essential. Both between incident personnel and UAS crew to understand the capabilities and limitations, and within the UAS crew between vendor and UASM/UASD to understand mission requirements and desired products/outcome.
    - Multiple LRZs may be required. We ended up with seven different locations as the incident grew, link issues, terrain, and the need for data connections.
    - Distributed FMV may not be the best option if the accuracy issues aren't able to be engineered out. Alternative means of distributed intel should be investigated.

5. **Going forward:**
    - Test functionality of Silvus radio system.
        - FMV to users in the field
        - VoIP communications from field to UAS Module
        - Push updated map layers or imagery to field
        - Collect intel from field if determined useful
    - Test functionality of ATAK system as intel distribution platform.
    - FirstNet hotspot available as part of kit for improved data connections.
    - Determine viability of primarily flying mapping missions to maintain Gimbal accuracy while also providing timely intel to the field.
        - How often does the field need updated intel? Is real-time required?
        - Is a point/line/polygon over an OPS map acceptable intel for burnout operations? Hot spot detections?
        - Is there value to multiple map collections in one operational period for modelling or planning?
    - Investigate potential of additional person in UAS module to gather user requirements for intel and build/maintain distribution systems when LTE isn't available and use of MANET or P25 Radios are needed to send basic GIS data over ATAK.
        - Georegister imagery from mapping missions to create points/lines/polygons based on user needs (Fire location, fire spread estimates, fire spread rate per fuel, fire location vs containment)

    - Investigate workflows that maximize outputs from UAS Imagery/Video to support multiuse intel (LTAN, FBAN, BAER, OPS)
    - Manage/Deploy hardware kits (To be developed based on identified needs)
    - Supplement UASD with distribution/setup tasks to reduce workload in larger fires
- Improve real-time mapping capability:
    - Stream mapping camera photos while still in flight
    - Various software systems that can stitch photos onboard aircraft, or as they are streamed.
- Vendor improvements possibly available next year:
    - Gimbal system for mapping camera to maintain nadir position.
    - Improved accuracy of camera positioning through FMV.
    - Multi-lens camera that can be adjusted for field of view depending on mission/product needs.
- Working with potential vendor of Jagwire which is owned by Harris, who also happens to own the Latitude aircraft.
    - Jagwire to provide FMV support.
    - Also perpetual catalog of data collected.
    - Advanced Artificial Intelligence mechanisms for multiplying the utility of the data being collected (i.e. real-time fuel behavior).

6. **Other Data Requests** – While on incident, others requested access to the UAS data:
    - Public Relations was interested not only in the UAS story, but how the UAS data could be used to report on the fire. Here's a link to a UAS story done on the Bighorn and Sawtooth
    - Fire Behavior Analyst Brian Anderson contacted us for Zoom info and videos.

7. **References (Request Access through Rich Thurau: richard_thurau@ios.doi.gov):**
    - UASD Python scripts, links to account setup (EGP, AGOL, FTP)
        - Here
    - Screen recordings and gimbal camera video
        - Here
- Sample mapping camera photos
    - Here