USDA Phase II SBIR: TACFI-RS

Title: Airborne Wildfire Mapping Utilizing an Array of Thermal Infrared Cameras and Automated Multi-Aperture/Multi-Platform Fire Map Processing

NASA Phase I SBIR:

UTM Concept Demonstration for 24Hr Fire Fighting

Fall 2022 - Tactical Fire Remote Sensing Advisory Committee Meeting

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AGENDA

- ## TACFI-RS USDA PHASE II SBIR
  - Overview of TACFI-RS Concept
  - Phase I Concept Demonstration Results
  - Phase II Full Prototype Plans and Areas for Collaboration

- ## NASA Phase I SBIR: UAS Traffic Management (UTM) Concept Demonstration for 24 Hour Aerial Firefighting
  - Phase I Overview
  - Areas for Phase II Collaboration

Phase I Concept Demonstration:
Technology Convergence

- Miniature Thermal Cameras, Inertial Navigation Systems, and Processing can be combined in a way to enable placement of a small Fire Mapping Sensor on every platform participating in Aerial Firefighting:
    - "Tactical" Sensor to complement "Strategic" Sensors (National Infrared Operations - NIROPS and Satellites)
    - Low-Cost, Strap down Array providing Wingtip to Wingtip Coverage (No gimbal/moving parts)
    - No Sensor Console/Crew - Parasitic mission with ON/OFF Switch >> Automatic processing/Download
    - Direct to Map Products with Auto Fire Boundary >> No Thermal Imagery Interpretation
    - Air worthiness through FAA Form 337 "Minor/Major Field Modification" procedure
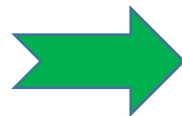

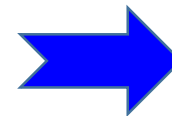Up to 9 Thermal Cameras 320x240 Un-Cooled LWIR

INS with 2X SBAS GPS

Compact Quad-Core Single Board Computers
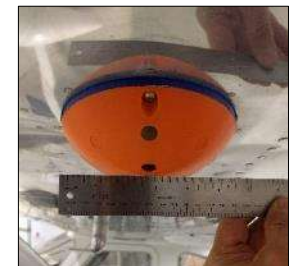
Innovative Packaging and Software

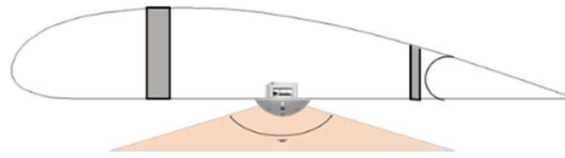**Nearly Horizon to Horizon Coverage with No Moving Parts**

"Field" Modification

Inspection Cover Mount

Size: 5.5"
Wt: 1.5 LBS
Pwr: 2A 12-28 VDC

Platforms: UAS to Lead Planes to SEATs to Large Tankers

TACFI-RS INSPECTION PORT
MOUNTED FIRE MAPPING SENSOR

**GOAL: Make every Aerial Asset a Sensor Node**

Innovative Processing:
# Multi-Frame/Multi-Platform Direct-to-Map and Auto-Perimeter

- Hundreds of deployed sensors requires innovative real-time map processing
  - Overlapping Camera Frames / Overlapping Aircraft
- Map Data registered to common 1/3 Arcsec (~10M/30') Digital Elevation Model in time slices
- Animated fire map like Weather Radar including real time perimeter shape file
- Weight all sensors, including Satellite and NIROPS, based on Quality and Timeliness of Data
  - "Express the Best" data, but don't "Throw Away" low quality data in the absence of any other data
  - e.g. – Timely, low altitude, very high resolution data is weighed more heavily than aged, high altitude, lower resolution, data.
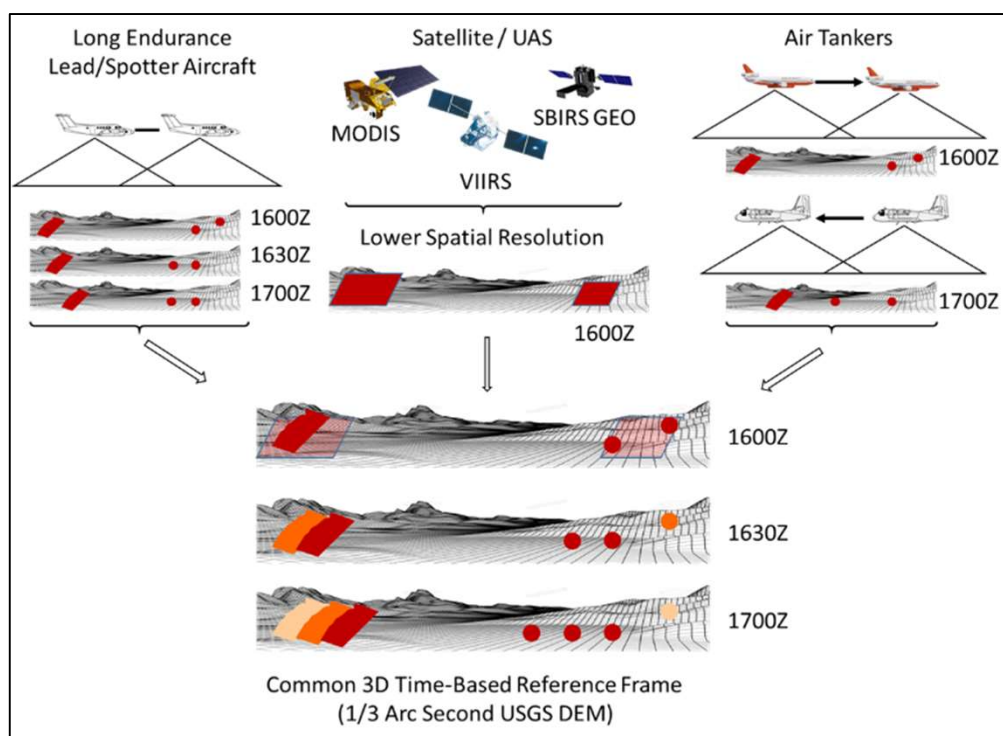
"Skinny" map data vice imagery is easy to share via narrowband links or cellular

Quantitative Testing:
Accuracy and Sensitivity
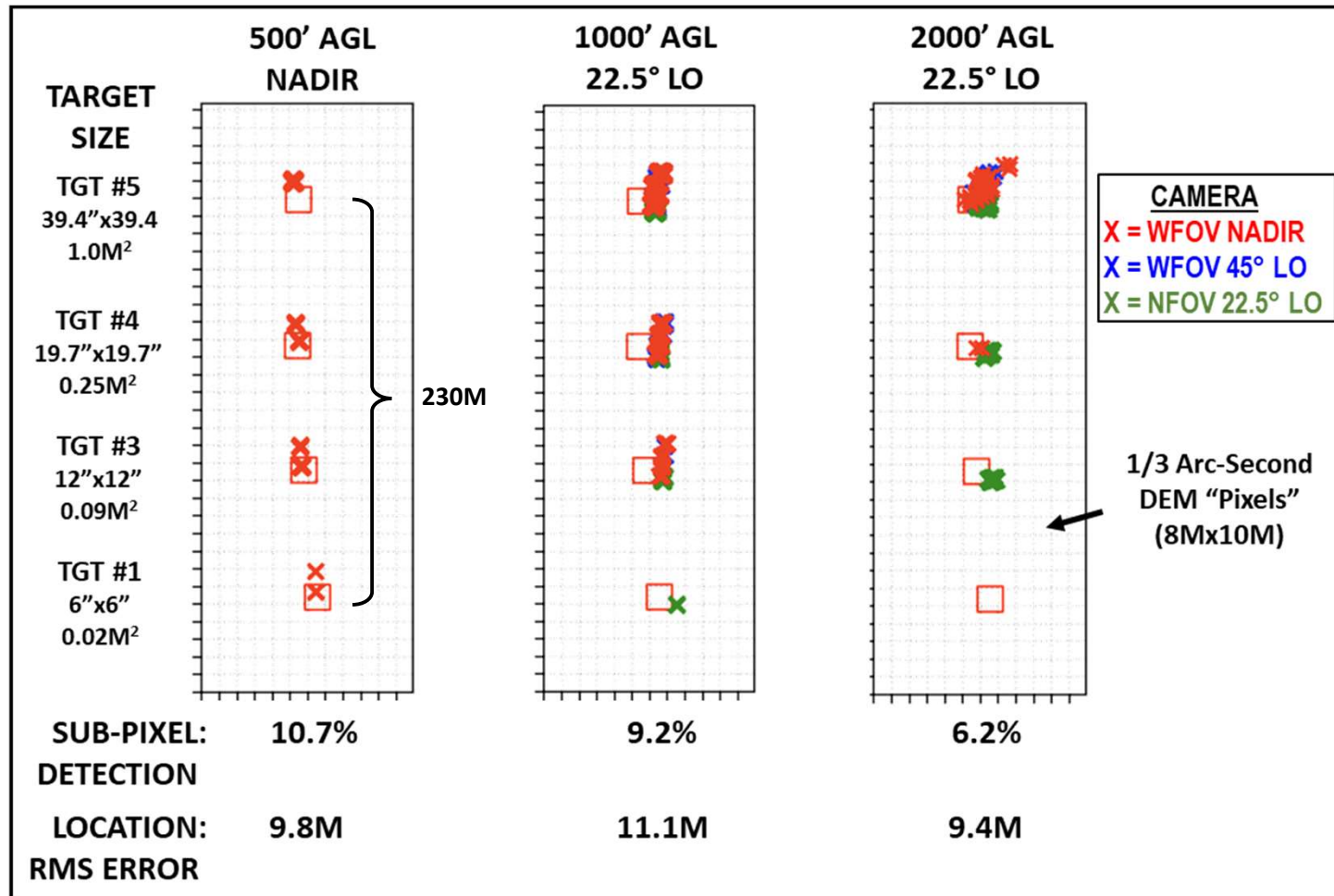
0.023M² ➡ 1.0M²
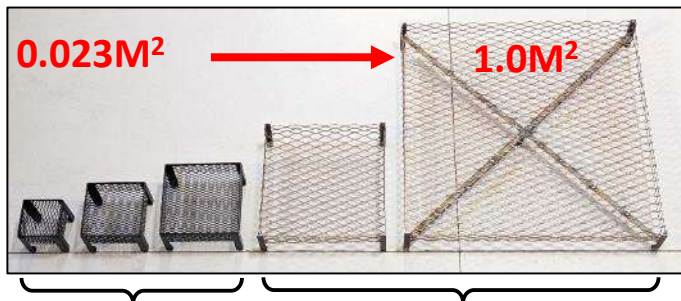
On Loan NIFC Targets   Locally Manufactured Targets

Sensor

- Conducted IR Target Testing to determine accuracy and sensitivity
  - Surveyed targets with 2x WAAS GPS
  - Flat Terrain: 19 Nov 21 @ Brigham City Airport (KBMC)
  - Mountainous Terrain: 23 Nov 21 Uinta Mountains near Oakley, UT
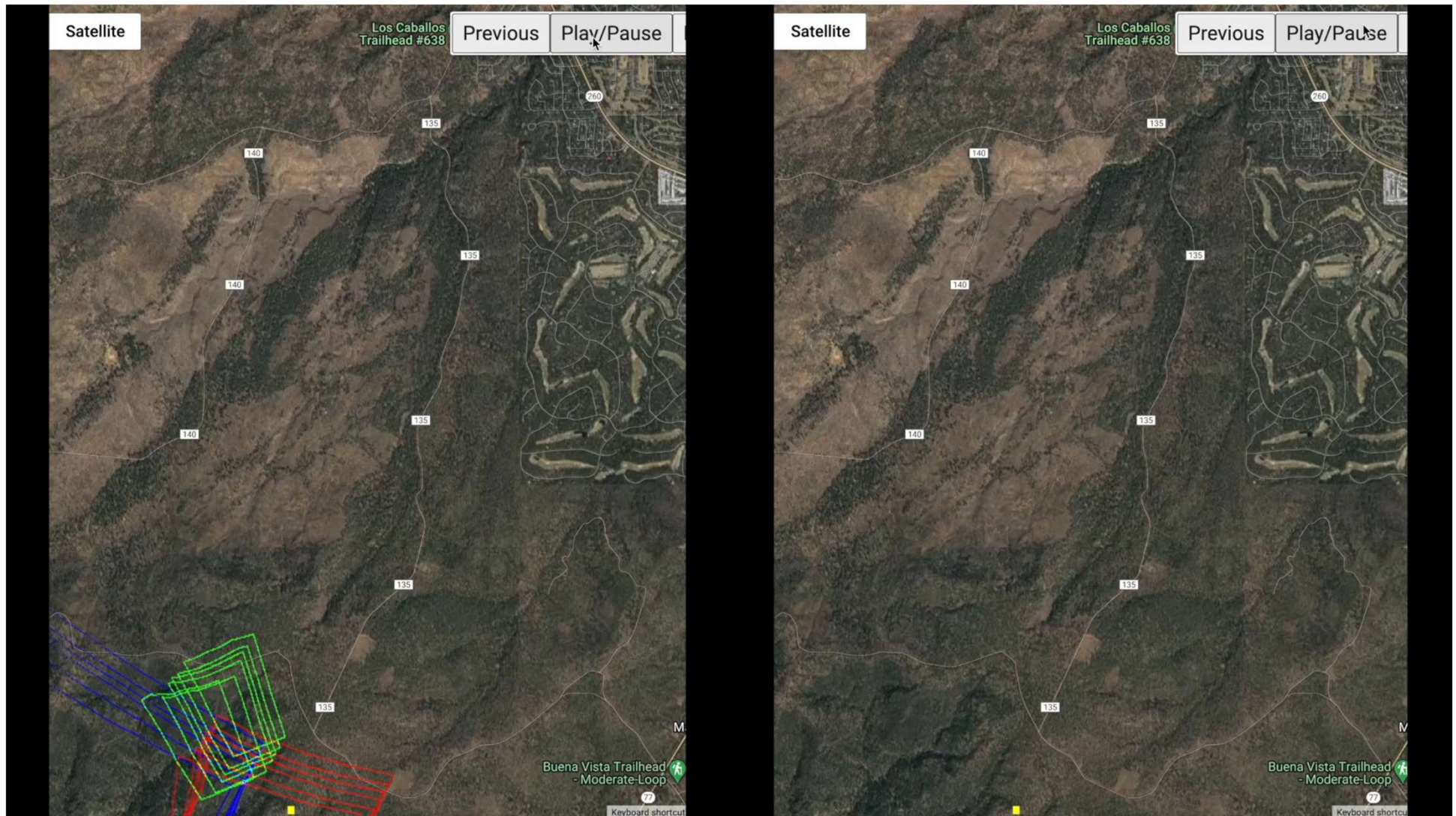
Results:
Level Terrain Testing

- ***Demonstrated 6-10% sub-pixel hot spot detection***
  - 6% Corresponds to the accepted limit for a single band sensor
- ***Demonstrated 10M "End-to-End" Geo-Location accuracy!!!***
  - Phase II improvements will drive to ~5M Accuracy

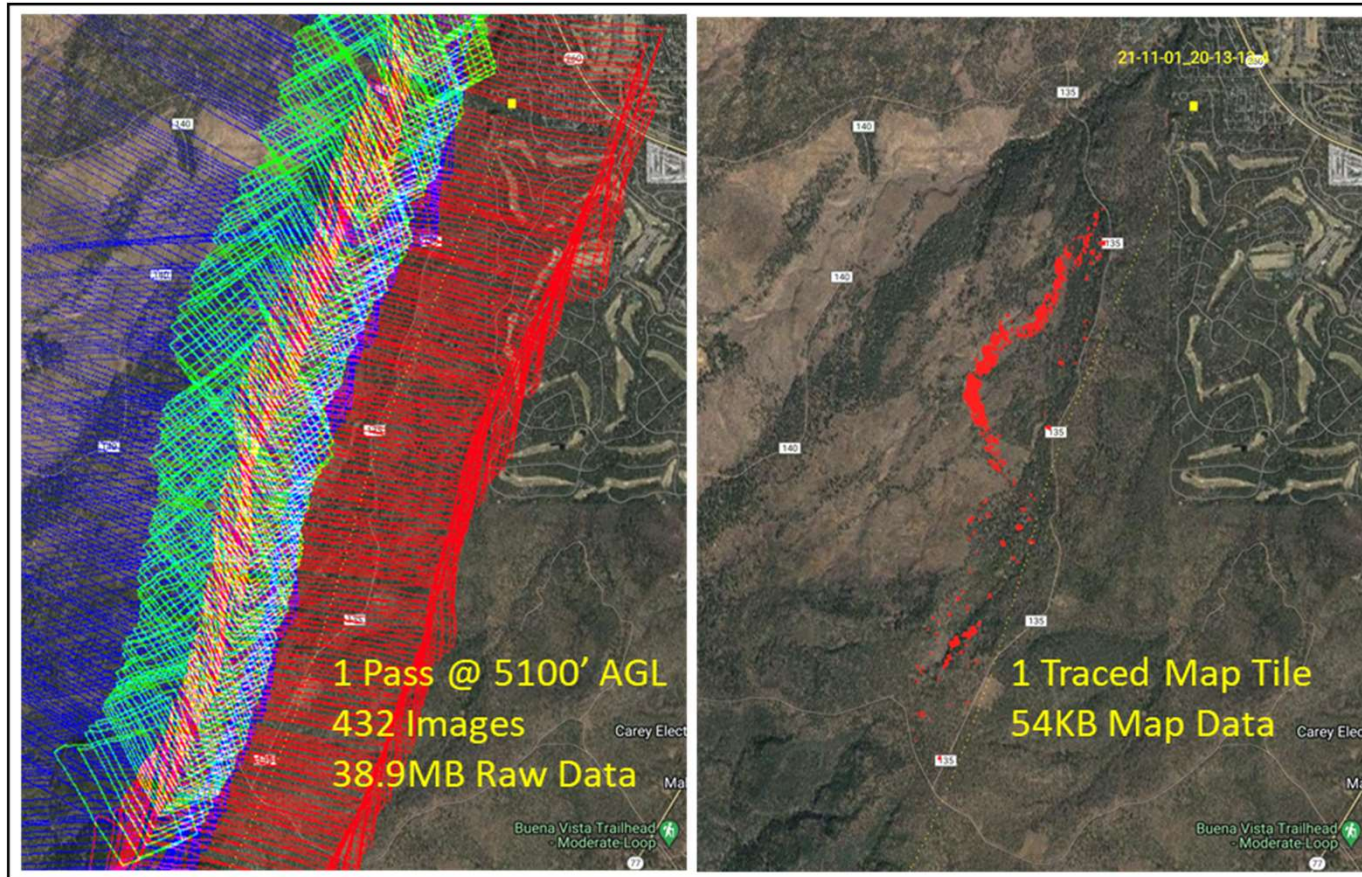 *Note: Altitude capped to 2,500' AGL due to cloud deck*

Single Pass Video - #1

TACFI-RS Last Pass Over Show Low AZ Prescribed Burn at 5,100' AGL.

Direct-to-Map Results In Significant Data "Compression"

1 Pass @ 5100' AGL
432 Images
38.9MB Raw Data

1 Traced Map Tile
54KB Map Data

- TACFI-RS Single Pass Over Show Low AZ Prescribed Burn. Foot print of 432 Overlapping Thermography Images comprising over 38MB of Raw Data (Left) representing ~100M temperature measurements is Reduced to 54KB of Direct-to-Map Product (right)

- Resulting Map Product is suitable for transmission across Narrow Bandwidth SATCOM Links (e.g. Iridium CSD)

4-Hours of Show Low Rx Burn Animation
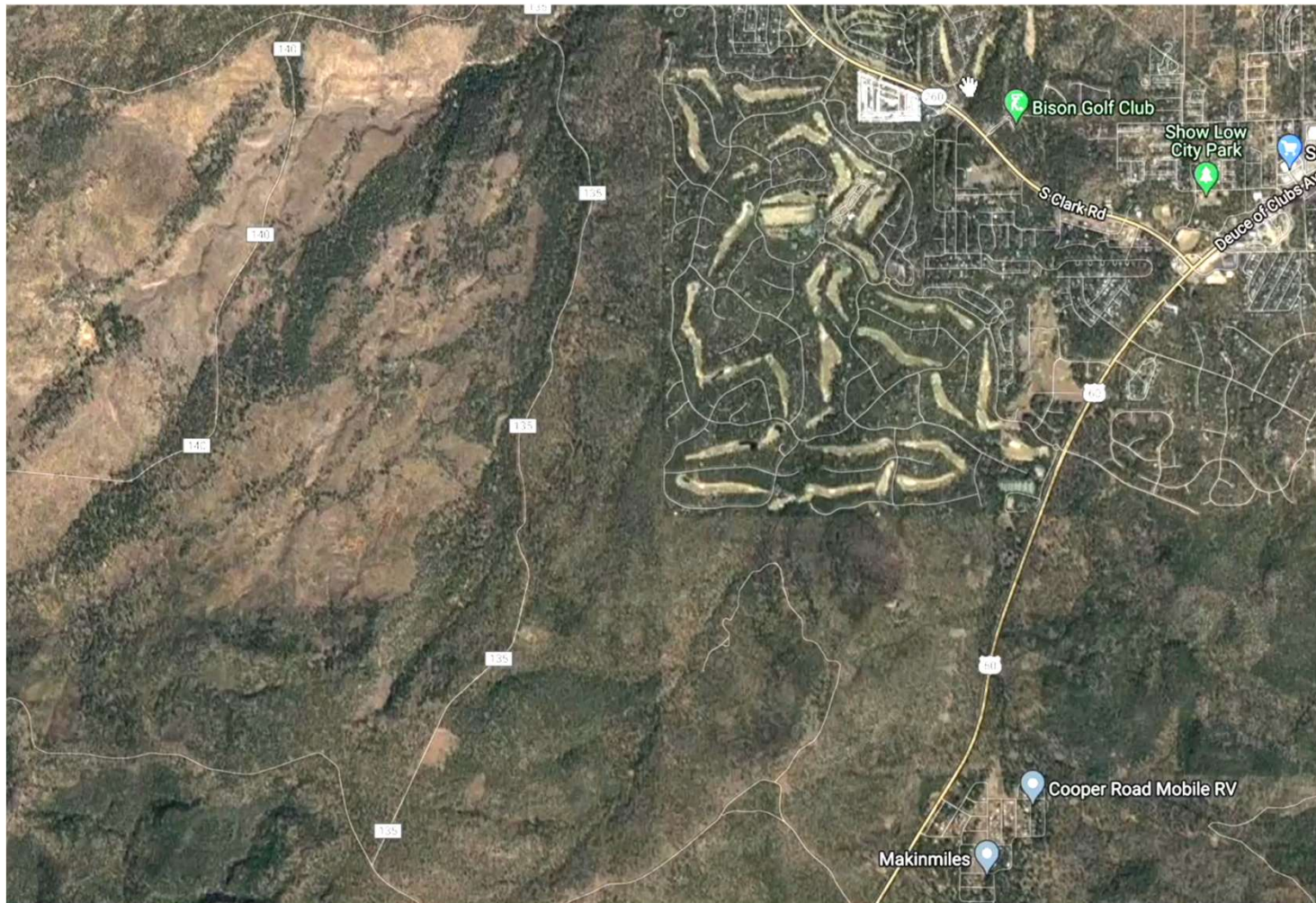
TACFI-RS Time Based Fire Map with Aging to Gray

Summary of Results

- Phase I Results:
  - Demonstrated Suitable Sensitivity for Tactical Fire Mapping
    - Excellent Bulk Fire Detection
    - Hot spots at 6%-10% Sub-Pixel Detection
    - NFOV TIR cameras will provide excellent capability to map bulk fire and large hotspots well above the TFR
  - Demonstrated Suitable Geo-Location Accuracy
    - ~10M with Path to 5M in Phase II (Improved INS and timing)
  - Demonstrated Mapping to 9,200' AGL (15,500' MSL)
  - Demonstrated Mapping during Maneuvering
  - Demonstrated Time Based Fire Maps with Simulated Multi-Platform Map Inputs
  - No Significant Sun Blooming >> Even from sun reflections on smooth water

Phase II: Sep 22 – Aug 24

- **Phase II Full Prototype**
  - Real-Time Map Processing
  - Beyond Line-of-Sight Map Transmission >> Iridium Certus 88Kbs SATCOM
  - Central Server Map Aggregation
  - Improved Geo-Location Accuracy >> Improved INS
  - Multiple Data Formats

- **Areas for Collaboration**
  - Combining time based observations with predictive models
  - Piggy backing other sensors/capability? >> Think of the sensor like a satellite bus with piggy backed payloads: Air Quality Sensing payload?
  - Firefighting data capture and effectiveness analysis >> Capture retardant release parameters for comparing against fire advance and fuel loads.
  - Application of AI/ML to hot spot detection algorithms
  - PILOT INPUT: What does a pilot want to see in the cockpit that can improve airborne firefighting efficiency? Lead plane vs Tanker?
  - Plume estimation >> Goes to supporting night time fire fighting

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- NASA Phase I SBIR: UAS Traffic Management (UTM) Concept Demonstration for 24 Hour Aerial Firefighting
  - Night, ground based aerial supervision for unmanned retardant deliveries.
  - Geared towards future 1,000 Gal Unmanned Air Tanker (UAT) or optionally un-manned SEAT but applies to current manned/unmanned operations
  - Leverage near real-time fire mapping
  - Web Based Tools: Retardant delivery and fire mapping mission planning, tanker dispatch, mission monitoring, exception handling, situational awareness information
  - UAS Avionics package (INS, ADC, Guidance Computer, BLOS SATCOM, TACFI-RS)
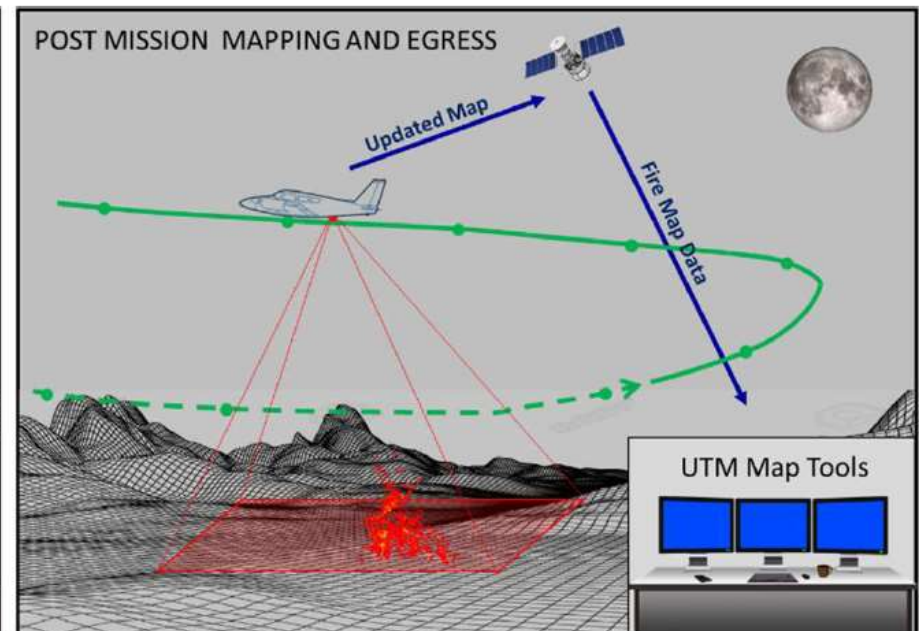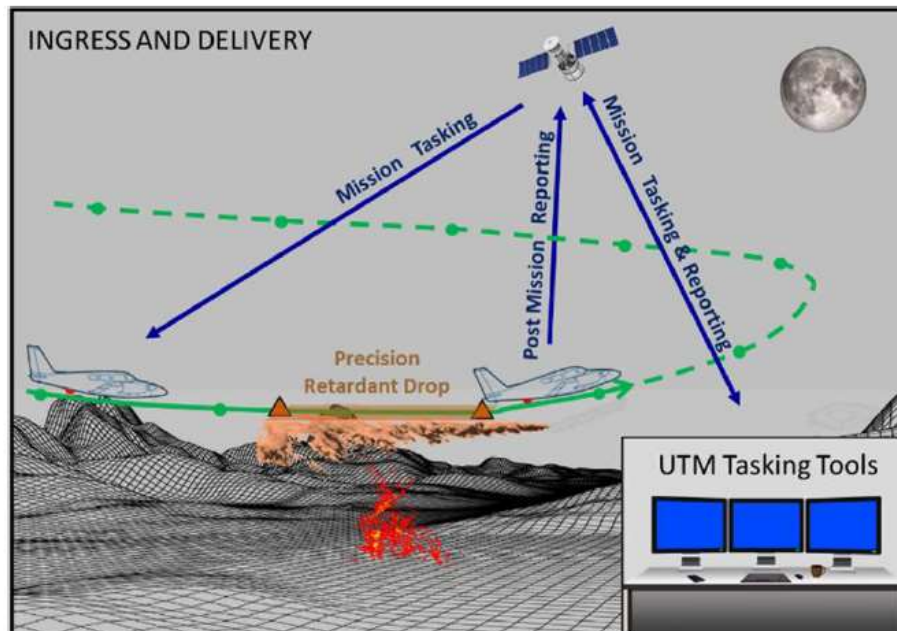
Airborne Concept Demo

- Phase I Concept demonstration using manned Light Twin
  - Similar performance as a 1,000 gal UAT or 800 gal SEAT
  - 3D ingress/egress trajectory while flying HUD Highway-in-the-Sky symbology
  - Wind corrected retardant delivery using guidance computer fed from Air Data – Inertial Navigation System (AD-INS)
  - Near real-time wildfire mapping with TACFI-RS sensor (USDA Phase I Concept Demonstrator)
  - Beyond Line of Sight (BLOS) communications via Iridium CERTUS

- Deploy to AZ in Dec 22 to conduct demonstration
  - Show Low AZ / Apache-Sitgreaves NF
  - Initially use pre-recorded Nov 21 Morgan Tank Rx Burn data
  - Looking for an Rx Burn or fires of opportunity for capstone exercise

SBIR Areas for Collaboration

- Mission integrity monitoring with LIDAR or RADAR
  - Back stop missions planned from 3D elevation models
  - Detect unknown hazards (wires, trees, towers etc)
  - Issue fly-up or mission termination

- Incorporate Fire Behavior Predictive Tools to extrapolate future fire boundaries

- Plume detection/avoidance >> Important for night UAS missions. Could be predicted via WX modelling or detected using LIDAR/RADAR

- 1,000 Gal Unmanned Air Tanker Design