TFRSAC Update October 2015

Wide Area Imager (WAI) Phase III Update
Thermal Mapping Airborne Simulator (TMAS) Phase II Update
Staring Wide Area Imager (StareWAI)Phase II Update

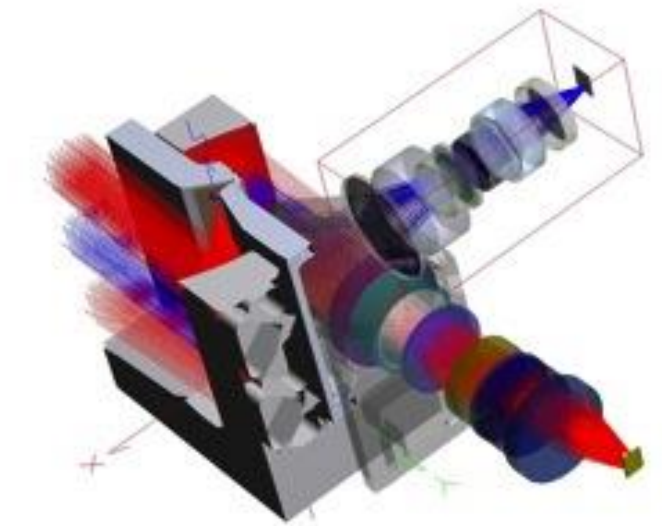
Unmanned Airborne Systems with Infrared Imager for Wildfire Mapping
(Phase I Proposal)

Xiomas Technologies, L.L.C.
Principle Investigator: John Green
johngreen@xiomas.com
734-646-6535

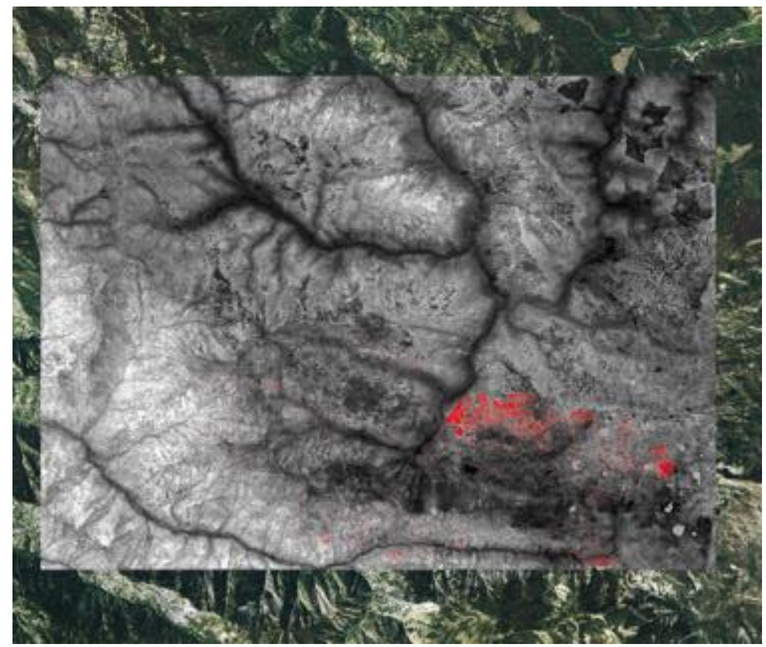
XIOMAS

About Xiomas --

- R&D for high performance airborne imaging systems
- Development of physics based models for remote sensing
- Software and computer engineering
  - Data acquisition, detection, identification, geo-location, and dissemination
- Optical Engineering
  - Hyperspectral imagers, thermal infrared imaging systems, multispectral imaging systems, and scanning imagers



Xiomas Hyperspectral Imager
developed under
U.S. Navy SBIR



Xiomas Thermal Image
with Fire Detection overlaid
on color photo

XIOMAS

Airborne Wide Area Imager for Wildfire Mapping and Detection (WAI)
Phase III Update October 2015

NASA PHASE III SBIR

PHASE II CONTRACT NUMBER

NNX09CA09C

Technical Monitor: Steve Dunagan

Xiomas Technologies, L.L.C.

Principle Investigator: John Green

johngreen@xiomas.com

734-646-6535

XIOMAS

<u>How are the Small Business Innovative Research programs structured?</u>

"The structure of the SBIR and STTR programs reflects the Congressional understanding that the innovation process and bringing new products and services to the market takes time and has a high degree of technical and business risk."

The programs have three phases:

Phase 1 is the opportunity to establish the scientific, technical and commercial merit and feasibility of the proposed innovation in fulfillment of NASA needs. All Phase 1 contracts are selected competitively and require reporting on the work and results accomplished, including the strategy for the development and transition of the proposed innovation. NASA SBIR Phase 1 contracts last up to 6 months with a maximum funding of $125,000

Phase 2 is focused on the development, demonstration and delivery of the proposed innovation. It continues the most promising Phase 1 projects through a competitive selection based on scientific and technical merit, expected value to NASA, and commercial potential. All Phase 2 contracts require reporting on the work and results accomplished, and whenever possible, the delivery of a prototype unit or software package, or a more complete product or service, for NASA testing and utilization. Both SBIR and STTR Phase 2 contracts are usually for a period of 24 months with a maximum funding of $700,000.

Phase 3 is the commercialization of innovative technologies, products and services resulting from Phase 2, including their further development for transition into NASA programs, other Government agencies, or the private sector. Phase 3 contracts are funded from sources other than the SBIR and STTR programs and may be awarded without further competition.

2.21 Technology Readiness Level (TRLs)

Technology Readiness Level (TRLs) are a uni-dimensional scale used to provide a measure of technology maturity.

Level 1: Basic principles observed and reported.
Level 2: Technology concept and/or application formulated.
Level 3: Analytical and experimental critical function and/or characteristic proof of concept.
Level 4: Component and/or breadboard validation in laboratory environment.
Level 5: Component and/or breadboard validation in relevant environment.
Level 6: System/subsystem model or prototype demonstration in a relevant environment (Ground or Space).
Level 7: System prototype demonstration in an operational (space) environment.
Level 8: Actual system completed and (flight) qualified through test and demonstration (Ground and Space).
Level 9: Actual system (flight) proven through successful mission operations.

We delivered the WAI in September 2010 and consider it at the low end of TRL7. Our flight test in June 2012 was at 10,000 feet, the low end of the "operational environment".

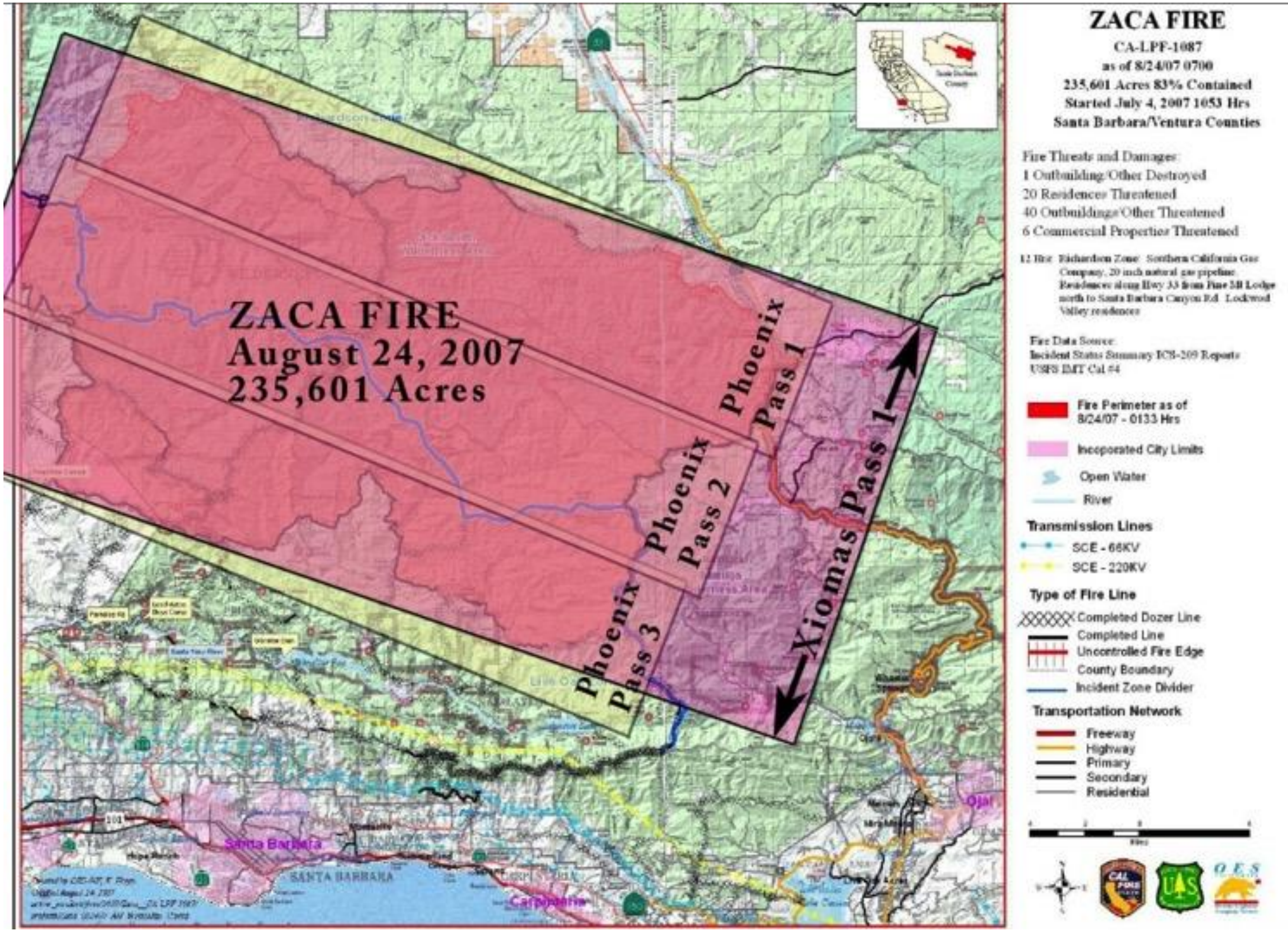
To transition to TRL8 we need to harden the system and complete several flight tests in the operational environment, i.e., USFS or NASA aircraft, and actual mission operations to take the system to TRL9.

Wide Area Imager for Wildfire Mapping

- NASA Funded Small Business Innovative Research Project
- Multi-Band System – 2 to 5 Bands
  - 2 Band QWIP for Mid-Wave and Long Wave Infrared
  - 3 Band Color Infrared Sensor (Green Red NIR)
- "Step – Stare" Optical System Combines High Resolution -- 300 uRadian and Wide Field of View -- 90 Degrees
- Data System Generates Fire Layer and Terrain Layer
- Real Time Orthorectification Processing Unit (OPU) generates GIS compatible Files
- Image Classification and Compression
- Data Transmission via Ethernet -- Air to Ground or Satellite --

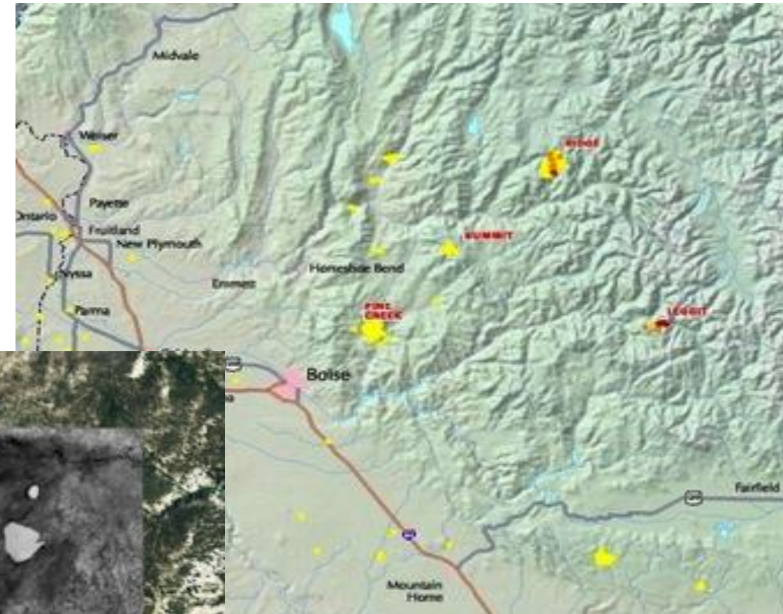
XIOMAS

Goal is to reduce operational costs by a factor of 2X to 3X by increasing coverage rate and decreasing flight time



Coverage of the current Phoenix system operated by the U.S. Forest Service National Infrared Operations group. The Phoenix system has a 120 degree field of view and covers a swath approximately 6 miles wide from 10,000 feet. At this altitude the Phoenix system has a 12.5 foot pixel at nadir. The proposed Xiomas system will have a 12.5 foot pixel from 42,500 feet and approximately a 16 mile swath width resulting in a 3X increase in coverage.

Wide Area Imager Fire Mapping Evaluation/Demonstration Mission --
Multi-day mission conducted July 23-26, 2013 over active fires near Boise Idaho

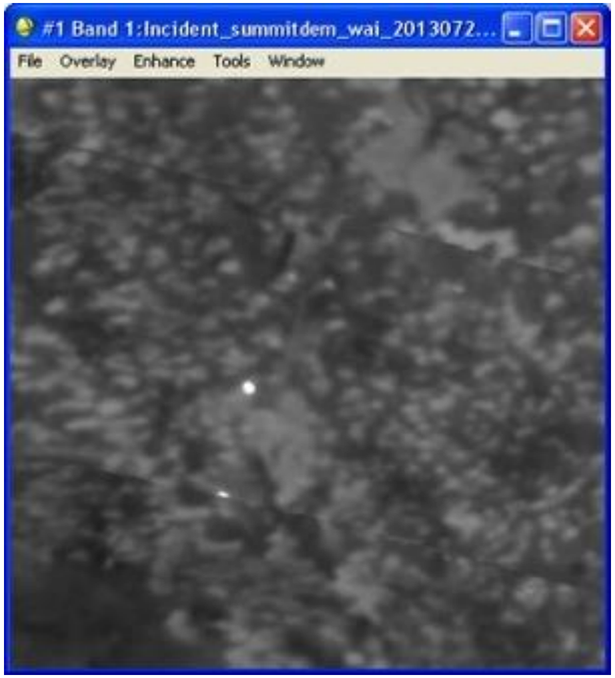


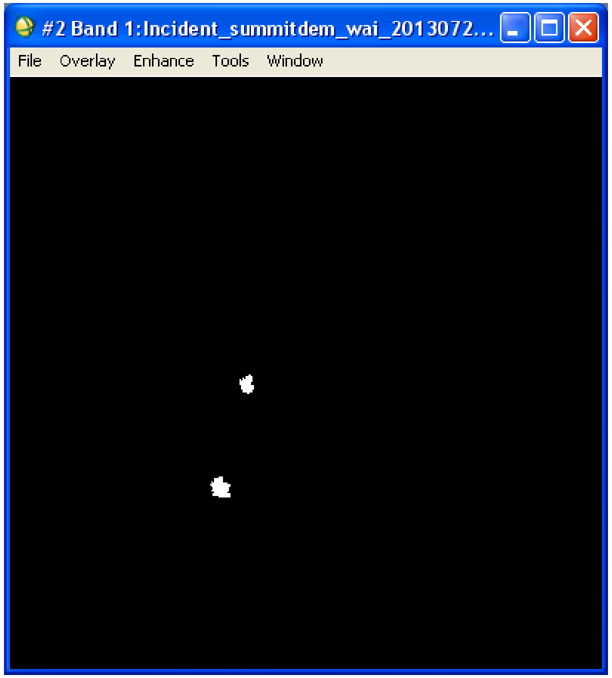
In total, the WAI has flown about 30 flights, including a number of engineering tests, calibration flights, several flights for two commercial imaging projects, and the fire mapping flights

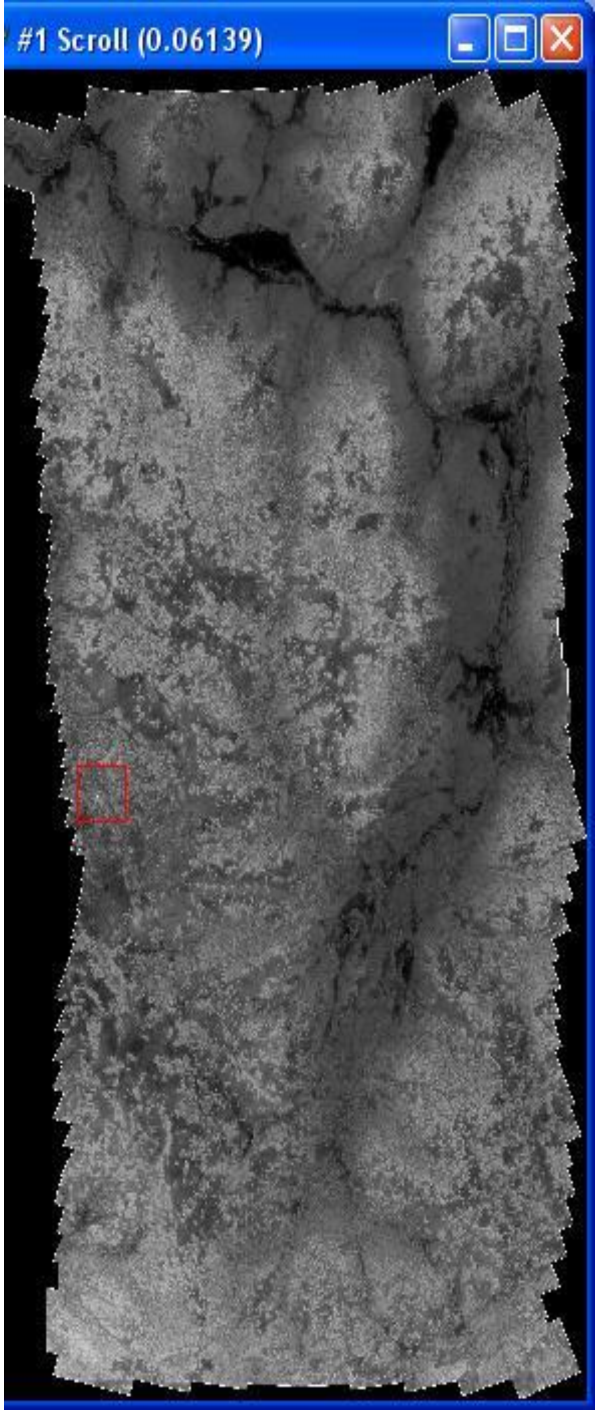
2013 USFS Test Flights

Flight operations generally occurred between 10:30 pm and 2:00 am. Immediately following the flight Xiomas delivered the orthorectified imagery to the USFS, briefed the USFS personnel on the flight and any items of interest in the imagery, and participated in the evaluation of the imagery by USFS personnel.

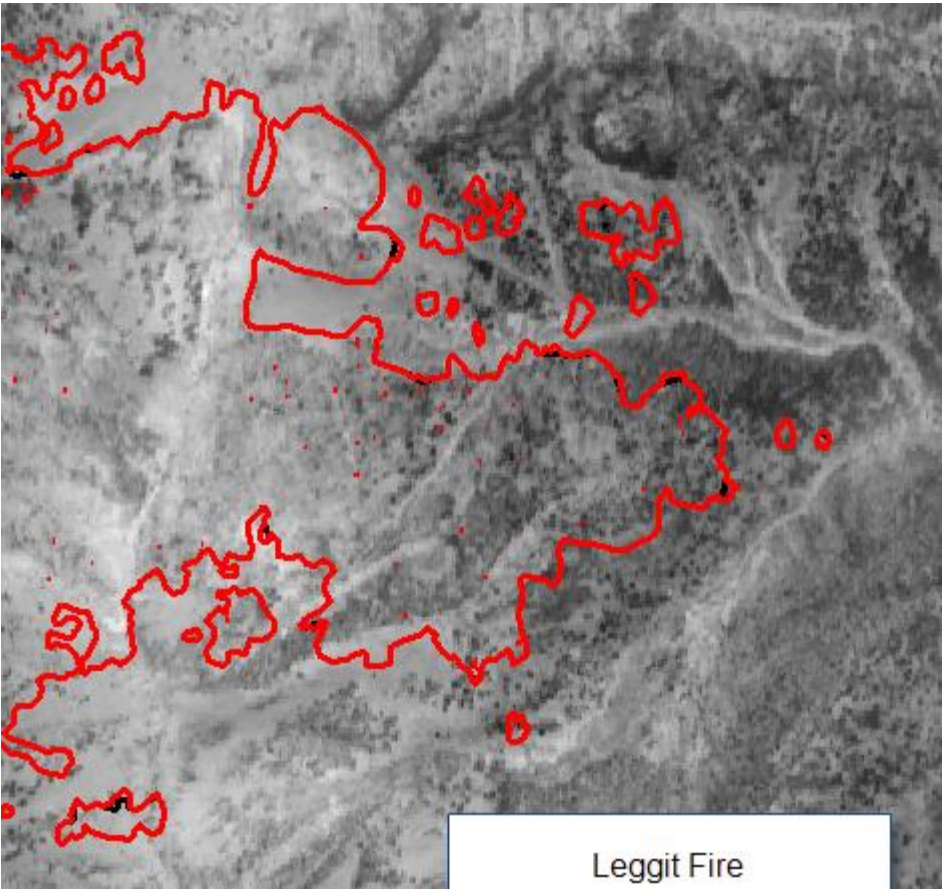
In general the USFS and Xiomas agreed that the registration of the WAI imagery to the reference base imagery (NAIP) was very good, with some occasional mis-registrations up to 10 meters, the detail in the LWIR WAI imagery was very good with small features such as drainages, structures, and roads, clearly visible, and the fire detection was very similar to the USFS Phoenix system.



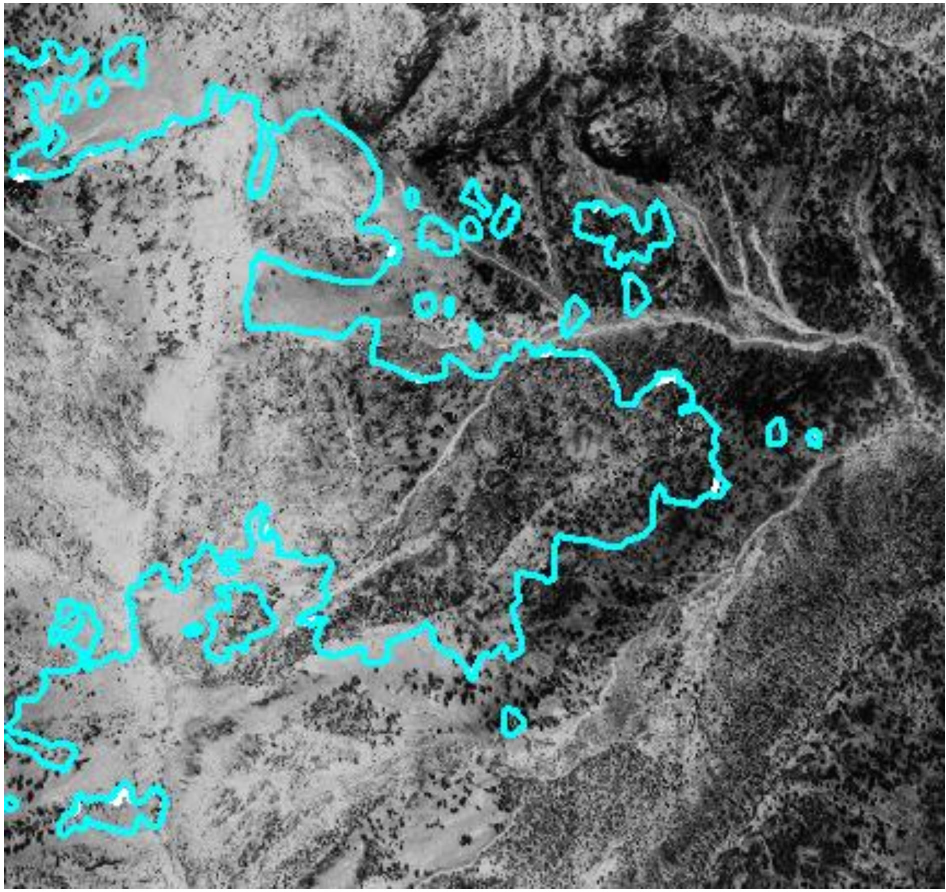




2013 USFS Test Flights



Phoenix Imagery



WAI Imagery

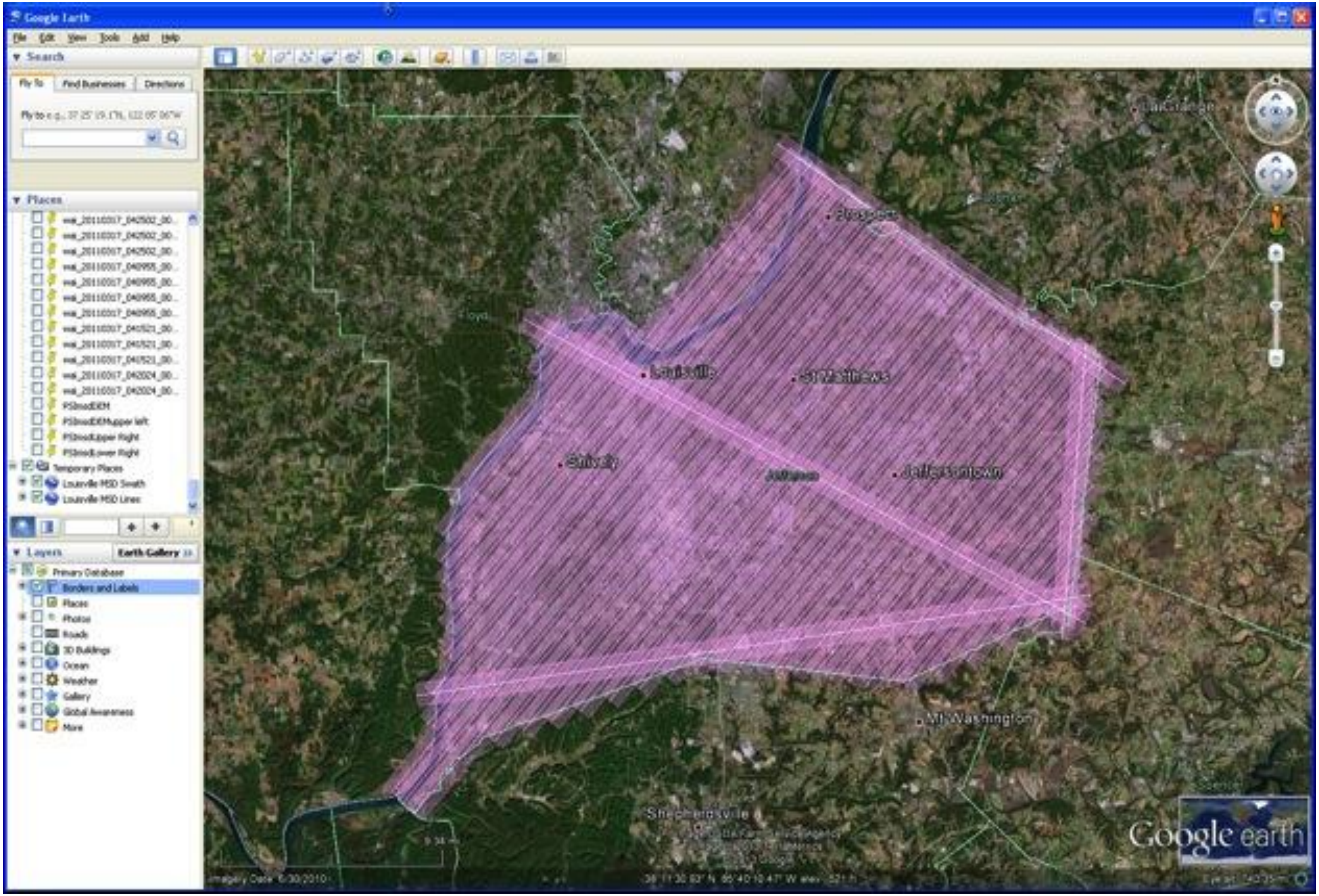
Both data sets are collected around the same time
and from around the same altitude (9,000 foot AGL)

Xiomas WAI 2013 Thermal Imaging project over Jefferson County KY for Photo Science (Quantum Spatial Inc.)

The project was flown over three nights, January 4, 7 and 8, 2013.

The WAI performed reasonably well, we had some system faults that caused us to repeat or partially repeat 10 flight lines over the three nights (10 out of 70 total flight lines).

WAI Long Wave IR Image after processing. This is typical of the image quality of the data set.



Screen Shot of Flight Plan
The longest line is about 32 miles
Total of about 650 flight line miles

Wide Area Imager samples
January 4 to 8, 2013
Altitude is approximately
6300 feet AGL
aircraft speed is 140 knots.

XIOMAS

Wide Area Imager samples
January 4 to 8, 2013
Altitude is approximately
6300 feet AGL
aircraft speed is 140 knots.

Interesting LWIR image of Electrical Power Substation with two contrast stretches

XIOMAS

Xiomas WAI 2015
Thermal Imaging project over Jefferson County KY for Quantum Spatial Inc.

We flew the WAI over Louisville Kentucky in January and February 2015 with Quantum Spatial

We had a problem with the WAI missing camera triggers, this causes the real time imagery to be rather scrambled. The problem is very intermittent. Out of around 40 flight lines, we had about 10 with no problem, about 20 flight lines with 2 or 3 or three missing frames, and about 10 flight lines with many more missing triggers (up to 100 or so).

For reference, a typical flight line has about 3,000 frames.

We also had a number of problems with the aircraft and the QS provided Applanix POS

And we had the worst weather Louisville has seen in 100 years
(well not that bad , but it was pretty bad)

On the positive —
We used the new TMAS boresight process and that works very well. The new process results in measurable improvement in the geo-coding, but more importantly there is a substantial improvement in frame to frame registration.

XIOMAS

Xiomas WAI 2015

Thermal Imaging project over Jefferson County KY for Quantum Spatial Inc.

Quantitative results of WAI (TMAS) Boresight Calibration

Xiomas has developed a new boresight process as part of the NASA funded Thermal Mapping Airborne Simulator (TMAS) innovative research program.

The TMAS procedure yields an RMS error of 2.6 pixels compared to the old WAI procedure result of 3.2 pixels. More significantly , the TMAS Boresight results in much better frame to frame registration

Imagery from the Boresight Flight in Wisconsin (local temp -7 F)

XIOMAS

Xiomas WAI 2015

Thermal Imaging project over Jefferson County KY for Quantum Spatial Inc.

XIOMAS

Xiomas WAI 2015

Thermal Imaging project over Jefferson County KY for Quantum Spatial Inc.

XIOMAS

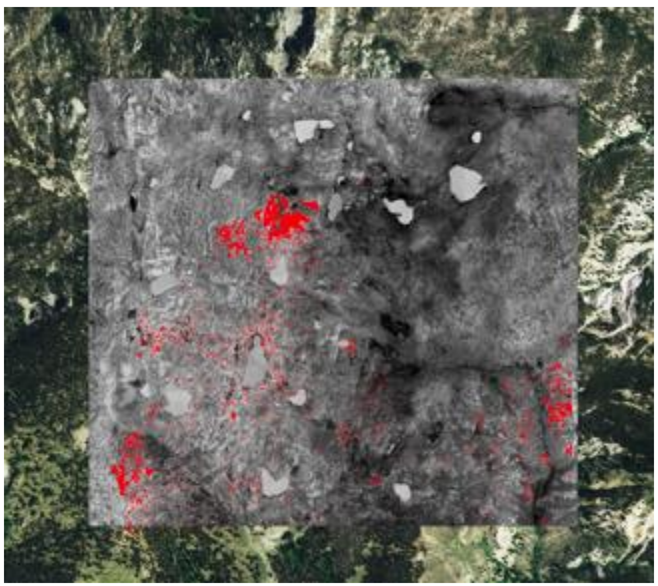
Xiomas WAI 2015
Thermal Imaging project over Jefferson County KY for Quantum Spatial Inc.

XIOMAS

In My 2014 we presented a paper titled:
Operational Test Results and Technical Description of the Xiomas Airborne Wide Area Imager
at the Large Wildland Fires: Social, Political and Ecological Effects Conference in Missoula
http://largefireconference.org/proposalspresentations/call-for-presentations/

Conference Proceedings were published in July

Presenter: Green, John, Principle Investigator, Xiomas Technologies L.L.C.
Additional Authors
Quayle, Brad, USDA Forest Service
Johnson, Jan, Remote Sensing Specialist, Red Castle Resources Inc.
Hinkley, Everett A., National Remote Sensing Program Manager, USDA Forest Service
Ambrosia, Vincent G. Associate Program Manager - Wildfire, NASA Applied Science Program



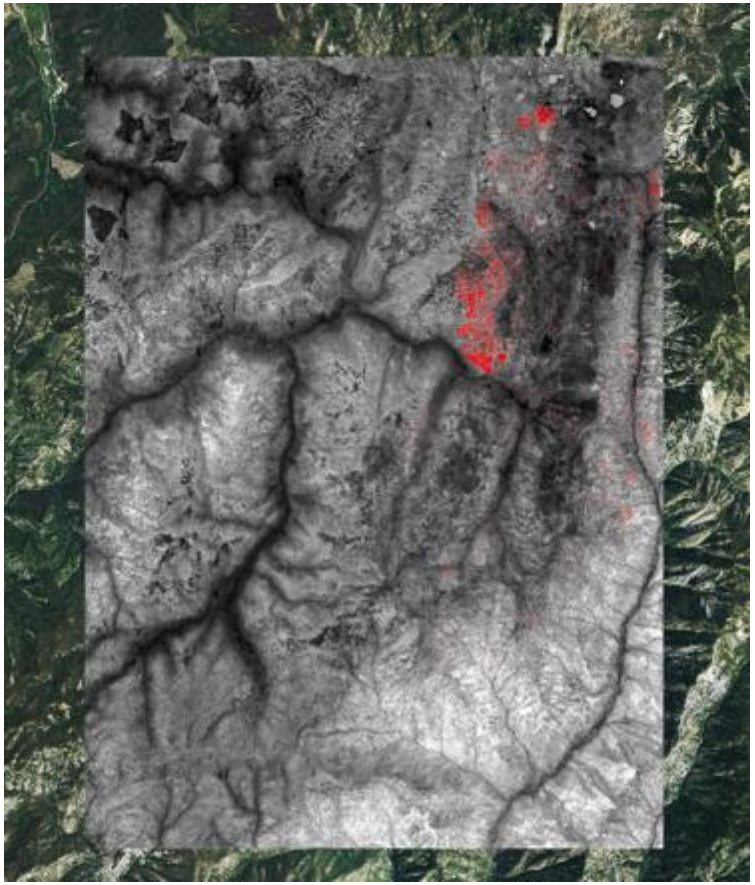
Large Wildland Fires: Social, Political & Ecological Effects

Discussion of Ongoing Development

Proposed further development of the Wide Area Imager

1)Hardening the system -- In general the system has performed well. Going forward we recommend upgrading the WAI phase II prototype to the new TMAS data system architecture.

2)Improve frame to frame registration – We see several examples where the imagery is shifted frame to frame. This mis-registration does not prevent the system from serving the fire mapping mission, but does raise some concerns as it is outside the expected performance. ---
DONE in 2015 USING TMAS Boresight



3) Automation and Remote Control of the operation – There are a number of features and planned improvements that we believe will essentially eliminate the need for an airborne operator, further reducing the cost of operation.

TMAS
Thermal Mapping Airborne Simulator
for
Small Satellite Sensor
Phase II
July 2013 to July 2016
Technical Monitor James Brass

Xiomas Technologies, L.L.C.

Phase II Contract Number: NNX13CA58C

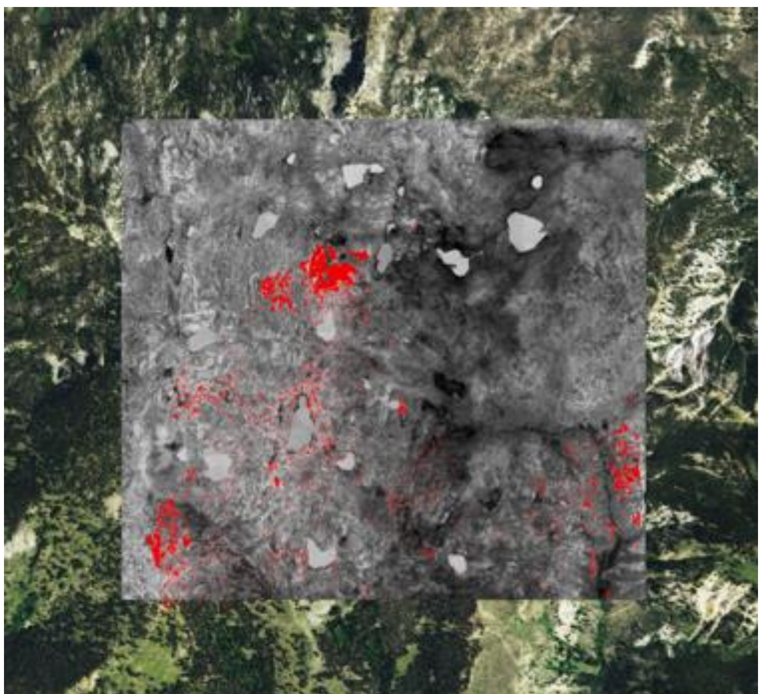
Principle Investigator: John Green
734-646-6535

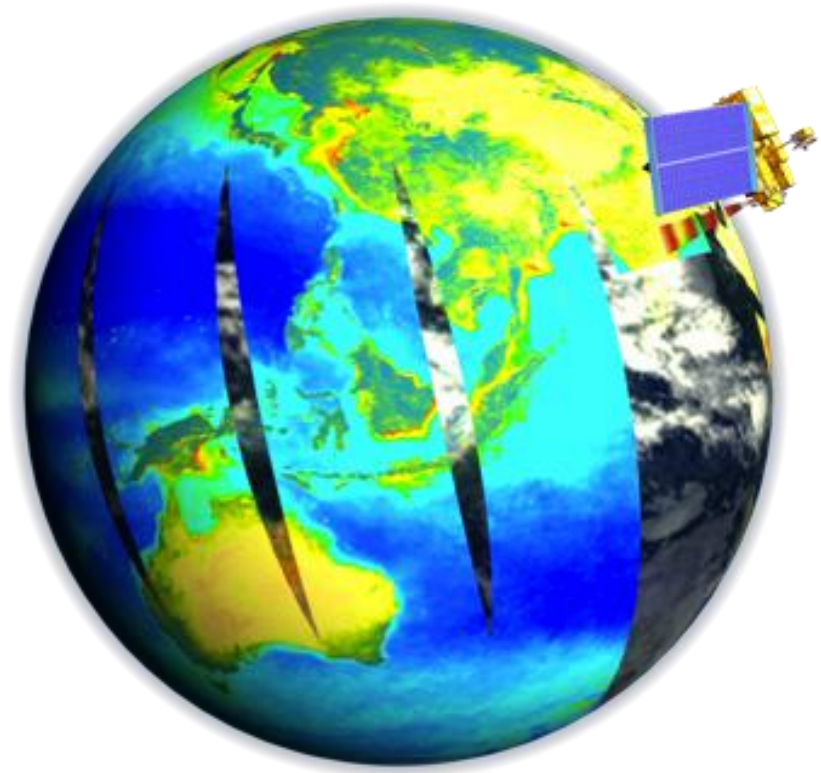
XIOMAS

TMAS

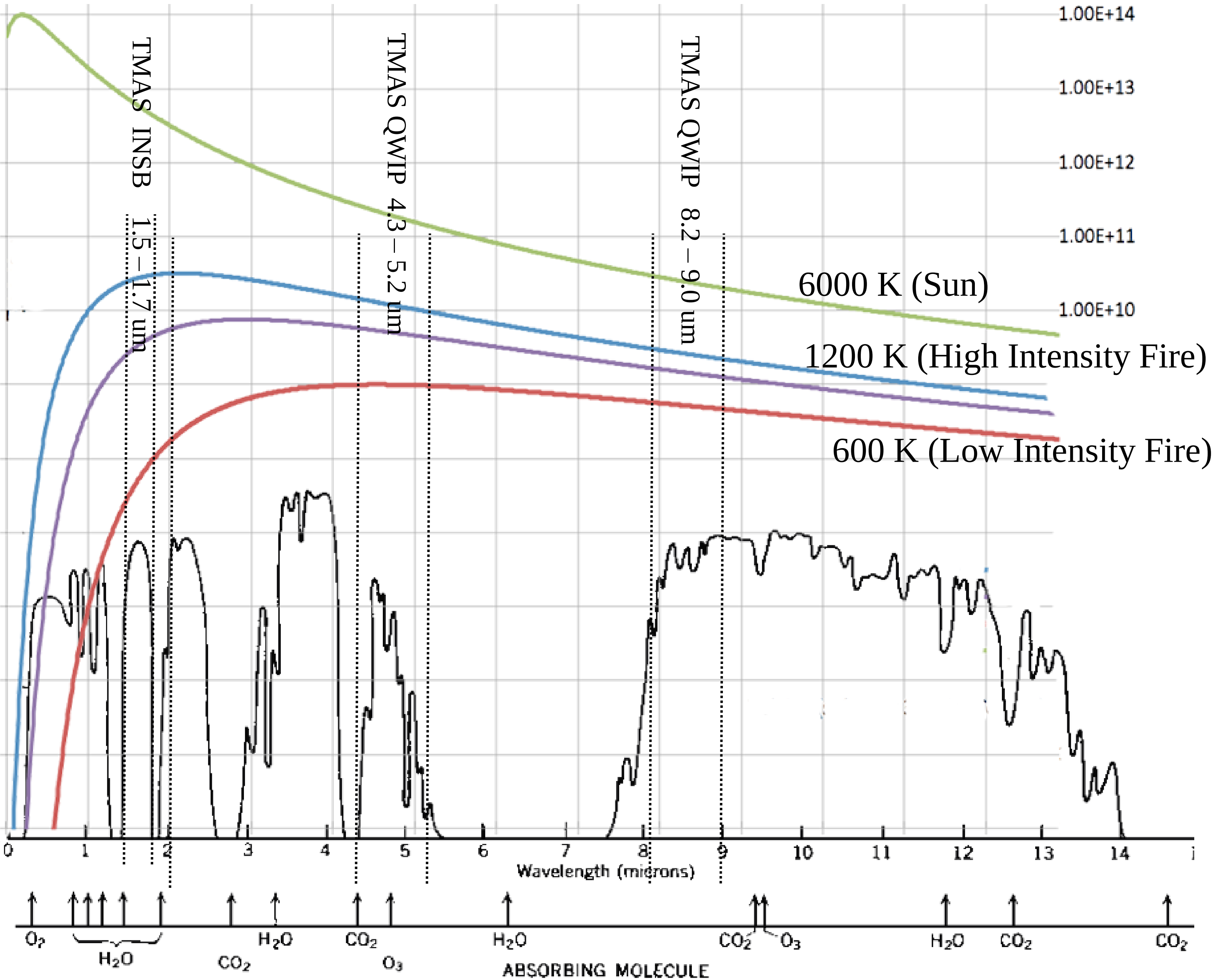
Operating at the same altitude and velocity as MODIS the TMAS will have the same capability to map the globe every one to two days

110 degree field of view (same as MODIS)
94 meter spatial resolution (similar to ASTER)
3 Spectral Bands (more can be added in Phase III)

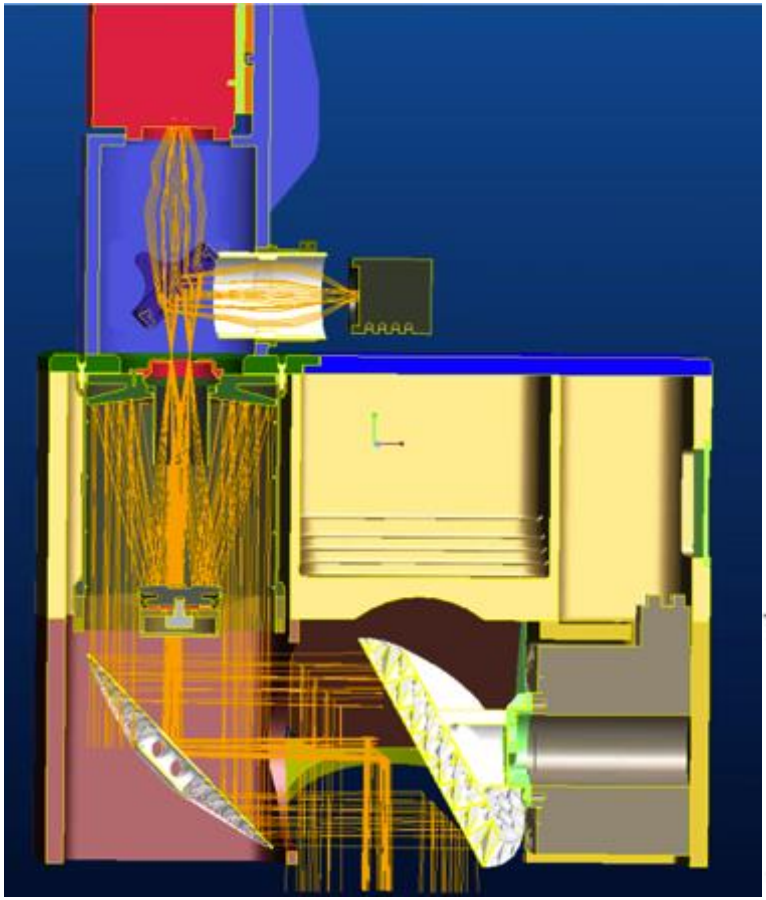




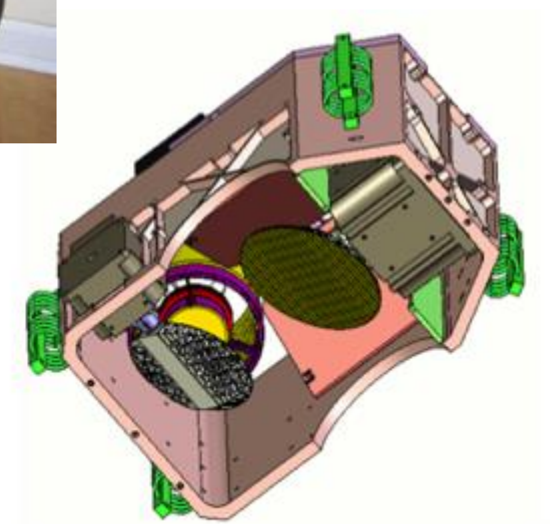
XIOMAS

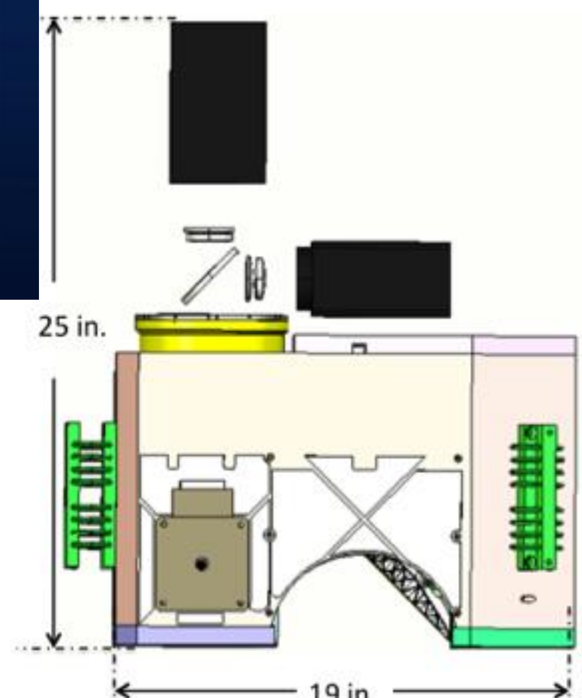


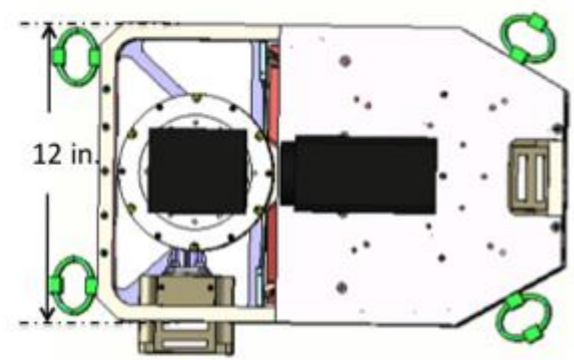
1.00E+14
1.00E+13
1.00E+12
1.00E+11
1.00E+10
TMAS INSB 1.5 – 1.7 um
TMAS QWIP 4.3 – 5.2 um
TMAS QWIP 8.2 – 9.0 um
6000 K (Sun)
1200 K (High Intensity Fire)
600 K (Low Intensity Fire)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
Wavelength (microns)
O_2
H_2O
CO_2
H_2O
CO_2
O_3
H_2O
CO_2
O_3
H_2O
CO_2
CO_2
ABSORBING MOLECULE



TMAS Acquisition and
Processing Unit

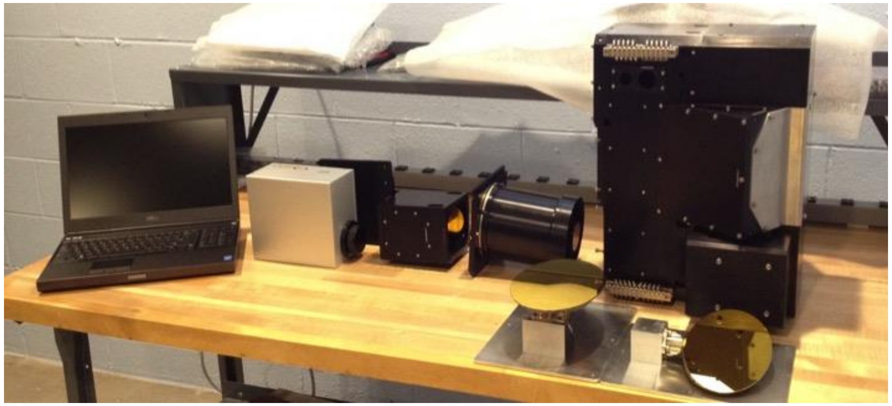






TMAS Telescope,
Sensor Array,
and Scan Head

TMAS Updated Schedule
October 2015 -- Integration and Test
November 2015 – Final Lab Tests and Acft Integration
December/January – Engineering Flight Tests
February/March – Operational Flight Tests
April and onward – Available for Operations



Staring Wide Area Imager
(STAREWAI)

USDA Forest Service Phase II SBIR

Award Number: 2013-33610-21054

Period of Performance September 2013 to September 2016

Xiomas Technologies, L.L.C.

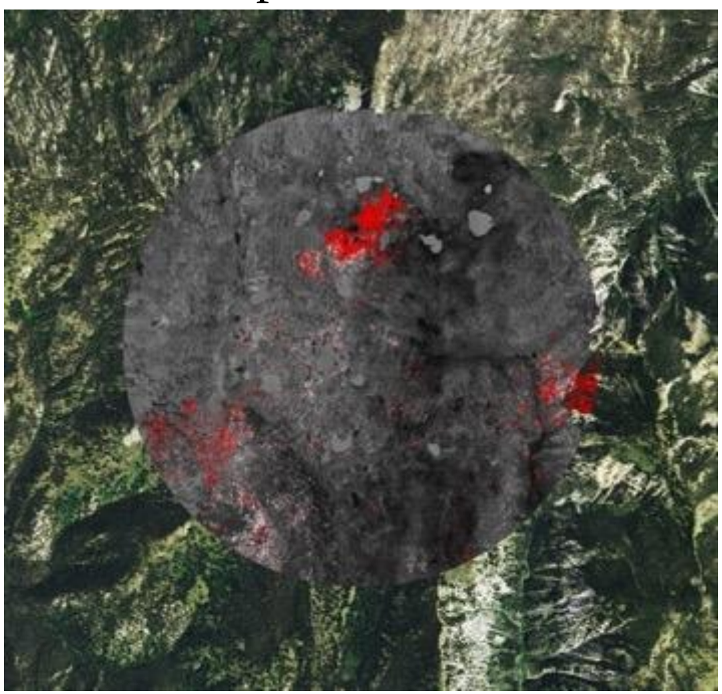
XIOMAS

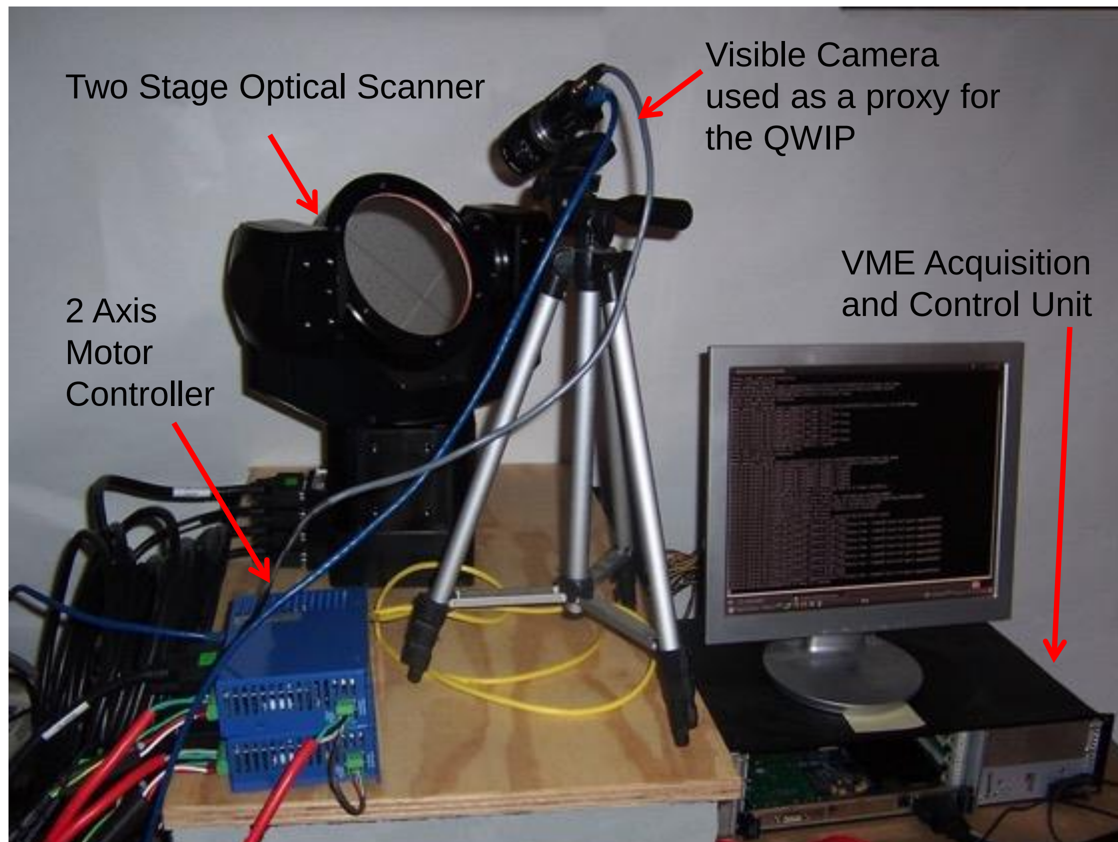
Staring Wide Area Imager (StareWAI)

In staring mode, the aircraft will circle a flight path similar to a typical holding pattern while the Stare Wide Area Imager continually scans an area.

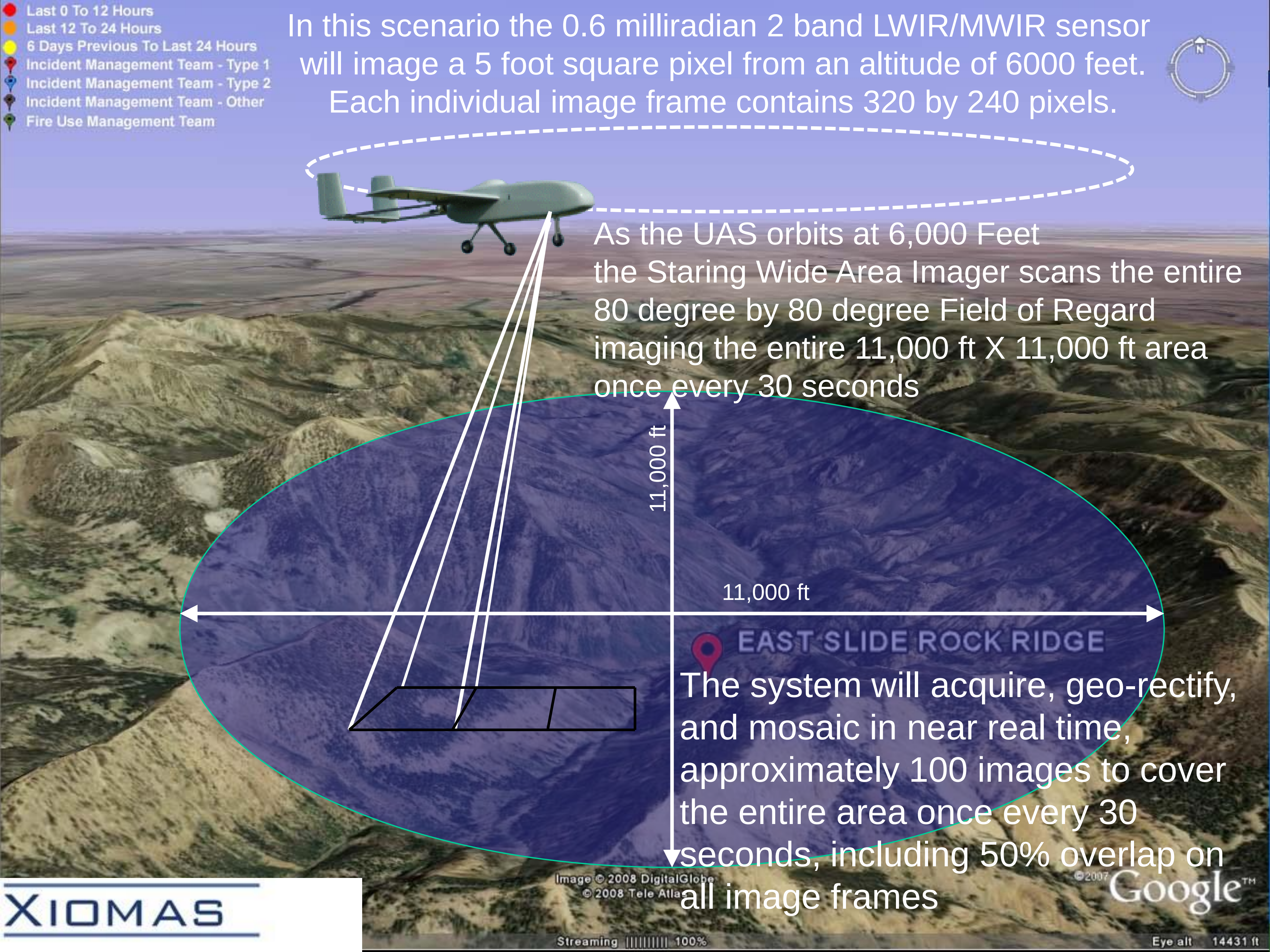
100 images will be mosaicked and placed on a map in real time every 30 seconds

The result is a moving thermal map of the area under surveillance, similar to a moving weather map





XIOMAS



Last 0 To 12 Hours
Last 12 To 24 Hours
6 Days Previous To Last 24 Hours
Incident Management Team - Type 1
Incident Management Team - Type 2
Incident Management Team - Other
Fire Use Management Team
In this scenario the 0.6 milliradian 2 band LWIR/MWIR sensor will image a 5 foot square pixel from an altitude of 6000 feet. Each individual image frame contains 320 by 240 pixels.
N
As the UAS orbits at 6,000 Feet the Staring Wide Area Imager scans the entire 80 degree by 80 degree Field of Regard imaging the entire 11,000 ft X 11,000 ft area once every 30 seconds
11,000 ft
11,000 ft
EAST SLIDE ROCK RIDGE
The system will acquire, geo-rectify, and mosaic in near real time, approximately 100 images to cover the entire area once every 30 seconds, including 50% overlap on all image frames
Image © 2008 DigitalGlobe
© 2008 Tele Atlas
©2007 Google™
XIOMAS
Streaming 100%
Eye alt 14431 ft

StareWAI Updated Schedule
December 2015 -- Integration and Test
January/Feb 2016 – Final Lab Tests and Acft Integration
March – Engineering Flight Tests
April/May– Operational Flight Tests (working with Matt Dickinson to fly prescribed burns in Ohio and Wisconsin)
June and onward – Available for Operations

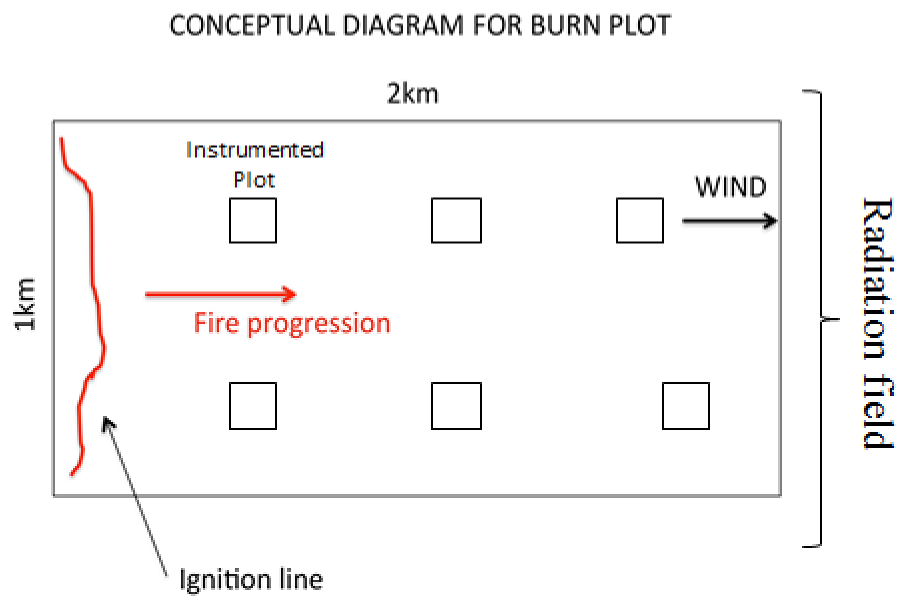


Figure 1. The radiation field will be measured from an infrared imager on an airborne platform and the fire will be coordinated with satellite imaging. Instrumented plots will occur on both low- and high-intensity fires, but a more comprehensive suite of measurements in instrumented plots will be possible in low-intensity fires.

Proposed Phase I USDA SBIR
Unmanned Airborne Systems with Infrared Imager for Wildfire Mapping

Xiomas and NCSU propose to develop systems, processes, and work plans, for the integration of Unmanned Aerial Systems (UAS) with Thermal Imaging into the wild fire management system, with a goal of providing the front line fire fighters and incident command with real time maps showing fire location and intensity, local terrain features, and incident command resource information (location of Crew Haulers, Incident Command Post, and fire crews).

We believe that no single solution exists, but envision several (2 or 3) UAS configurations including imaging, processing, and communication modules, integrated with a ground based portable graphic user interface, most likely running on either a rugged tablet or portable notebook computer.

Researching and developing the technology, i.e., specific aircraft, sensors, and image processing algorithms, is a key component of this research, however, we want to emphasize that the processes, procedures, work plans, and implementation plans are equally important and we anticipate roughly half the overall grant (phase I and II) will be used to support each (technology development and process development/integration). As mentioned we anticipate the development will result in 2 or 3 UAS configuration, but intend that Work Plans and Processes will be the same across platforms and will be scalable, and that the various systems will present the same "look and feel" to the end user.

XIOMAS NC STATE UNIVERSITY NGAT

NC STATE UNIVERSITY

NGAT Current Fleet with COA Locations

Vireo (FourthWing Inc)
[3 lbs, 2.5 ft wingspan]
- GRTS
- Caratoke
- Butner

Super Swiper (Bosh Technologies)
[9 lbs, 6ft wingspan]
- GRTS

Condor II (Bosh Technologies / Leptron)
[10 lbs, 6ft rotorspan]
- GRTS

Maveric (Prioria Robotics)
[3 lbs, 3ft wingspan]
- Butner

RMAX (Yamaha)
[100 lbs, 10ft rotorspan]
- GRTS

Lancaster (Precision Hawk)
[3 lbs, 4ft wingspan]
- Butner

T-20 (Arcturus)
[120 lbs, 20ft wingspan]
- Caratoke

Protector 10 (Bosh Technologies)
[36 lbs, 8.5 ft wingspan]
- GRTS

FENRIR (NCSU ARC Team)
[45 lbs, 10 ft wingspan]
- Butner

Short Description of Sensor Problems the Research will Address

Saturation and blooming – These are common problems that prevent quantitative measurement when imaging high temperature targets as the detector read out circuitry is designed to image "normal" temperature objects.

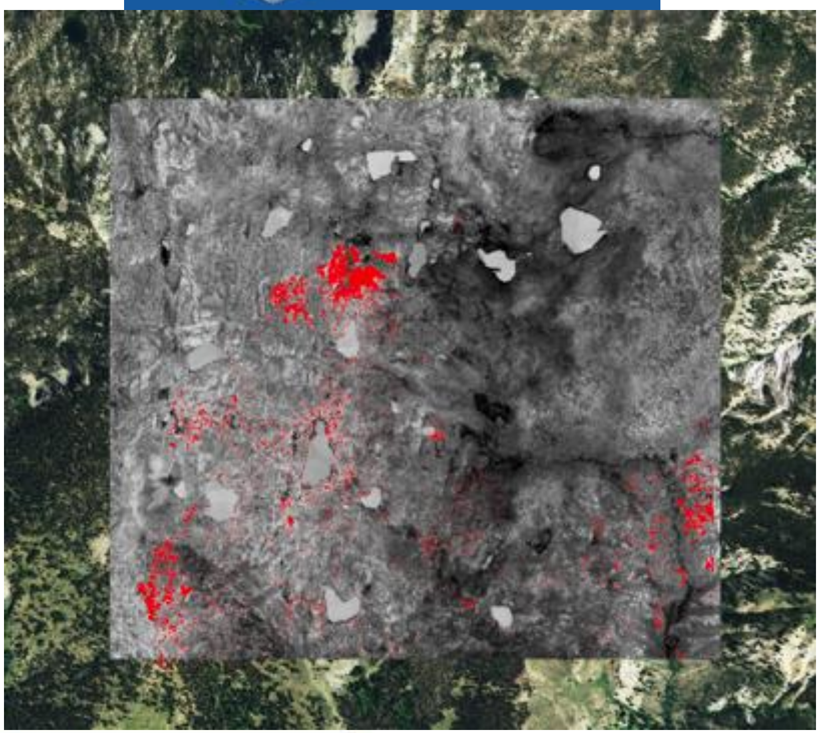
Radiometric Accuracy – Small thermal cameras are almost exclusively based on microbolometer technology. Generally speaking all sensors require some form of calibration if they are to deliver accurate measurements. Microbolometers have a number of attractive qualities, however, they suffer from thermal drift and non-uniformity across the focal plane, and in general calibration has proven problematic, especially in systems where size, weight, and power is limited.

Forward Motion Compensation (FMC) and pixel smear -- Microbolometers, require relatively long integration times. From discussions with FLIR, and other vendors, we estimate that normal terrestrial targets will require around 10 to 15 ms. When long integration time is combined with high spatial resolution in a moving platform (airplane) it is important to consider the amount of "smear" caused by forward motion during the sensor integration time.

For example at typical small UAV speed of 50 knots the forward motion of the aircraft will smear a six inch pixel by 250% during the 15 millisecond LWIR integration time (the aircraft moves about 15 inches while the "shutter" is open). This has the effect of greatly reducing the spatial resolution of the system.

Image To Base Map Registration – Registering the image to a base map is critical to delivering actionable intelligence to the end user. The usual solution is a high performance position orientation system with high update rates, but these are very expensive, and too heavy for most UAVs.

Questions?



XIOMAS

XIOMAS

JOHN M. GREEN
JOHNGREEN@XIOMAS.COM
734-646-6535

Research and Development of
Imaging and Data Acquisition Systems

WWW.XIOMAS.COM