Airborne Wide Area Imager for Wildfire Mapping and Detection (WAI)
TFRSAC Update November 2012

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

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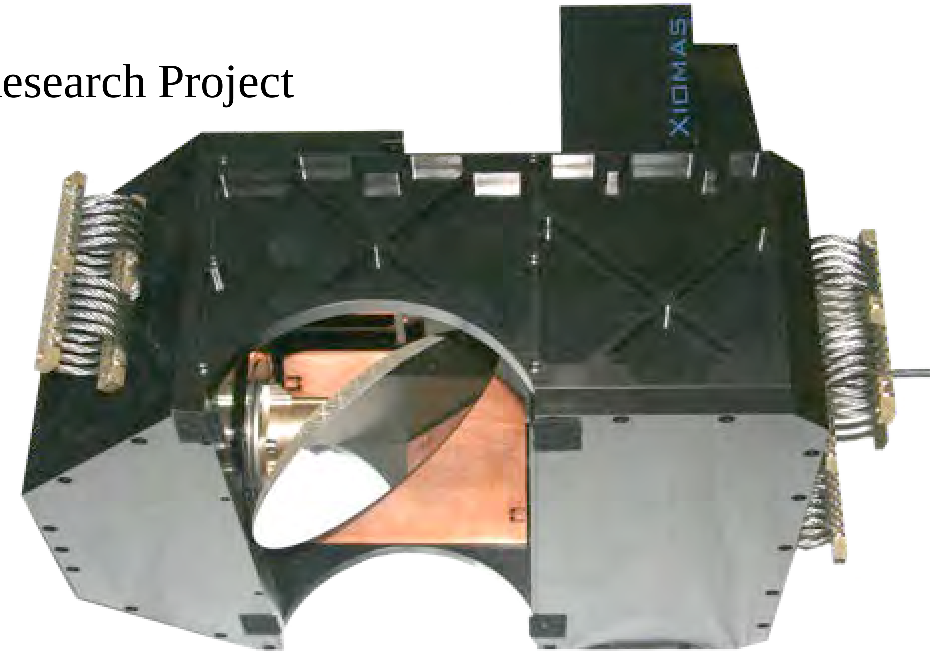
Wide Area Imager for Wildfire Mapping



- 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 --

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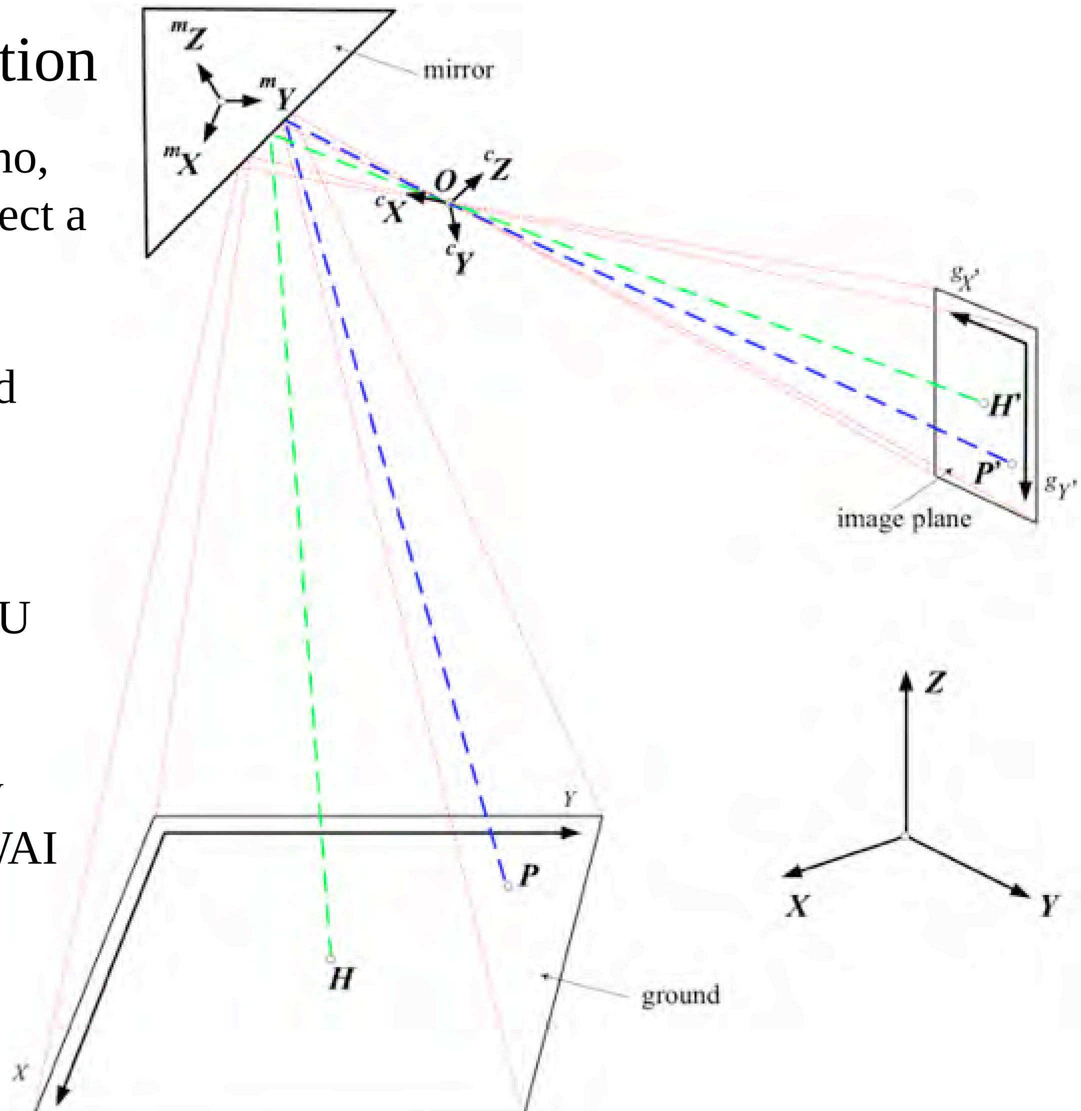
Summary of Bore Site Calibration



- The WAI sensor was flown over Reno, NV on July 11, 2011 in order to collect a dataset suitable for calibration and analysis of the system.
- The calibration process was modeled with two sets of 3-axis rotations (6 parameters)
  - one rotation modeling the transformation between the IMU and the camera optical path (standard boresight)
  - a second rotation modeling any residual rotation between the WAI scanning mirror axes and the optical path.
- Overall, this calibration approach proved successful, yielding a residual error of approximately 1 pixel RMS for image-to-image matching along a single flight line.
- Comparisons of multi-scan mosaics with existing visible-band image datasets indicates that the calibration is generally accurate to within 1-2 meters.

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WAI LWIR Mosaic and some zooms

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WAI MWIR Mosaic and some zooms

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#1 Resize (Band 1:Line4Mosaic16bitLW.tif):Line4NorthEndMosaic16bitLW.tif
File Overlay Enhance Tools Window
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#1 Resize (Band 1:Line4Mosaic16bitLW.tif):Line4NorthEndMosaic16bitLW.tif
File Overlay Enhance Tools Window

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#1 Scroll (0.07979)
#1 Band 1:Line4Mosaic16bitLW.tif
File Overlay Enhance Tools Window

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Wide Area Imager Update

The project to add a Color IR Sensor to the Xiomas Wide Area Imager is complete and the system is working well. The sensor integration went well, but took much longer than anticipated.

In summary the following was accomplished:

- Purchased the CIR camera
- Modified the WAI optical design to accommodate the new sensor
- Modified the WAI SW to accommodate the new sensor
- Modified the Orthorectification processing SW
- Modified the WAI Acquisition and Processing HW with the following components:
- OPU mother board upgraded to faster processors
- OPU memory increased
- Solid State disk drives upgraded to increase capacity
- Solid State disk drives upgraded to allow easy removal
- Flight tested the system
- Conducted D0160 vibration tests
- Performed Boresite calibration
- Integrated Boresite parameters with the WAI OPU

Update on the Wide Area Imager Phase III

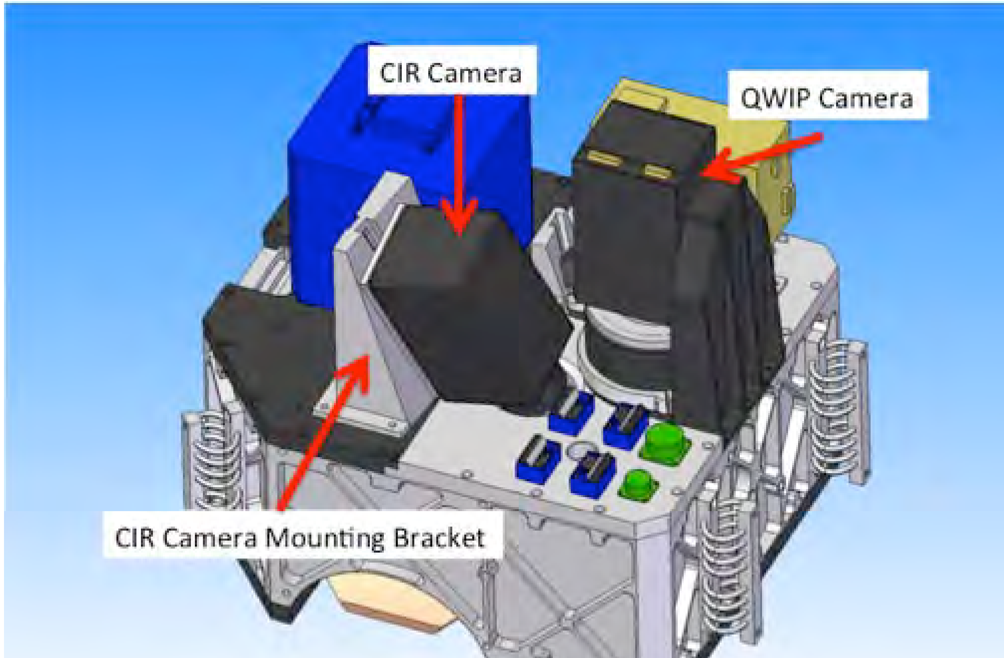
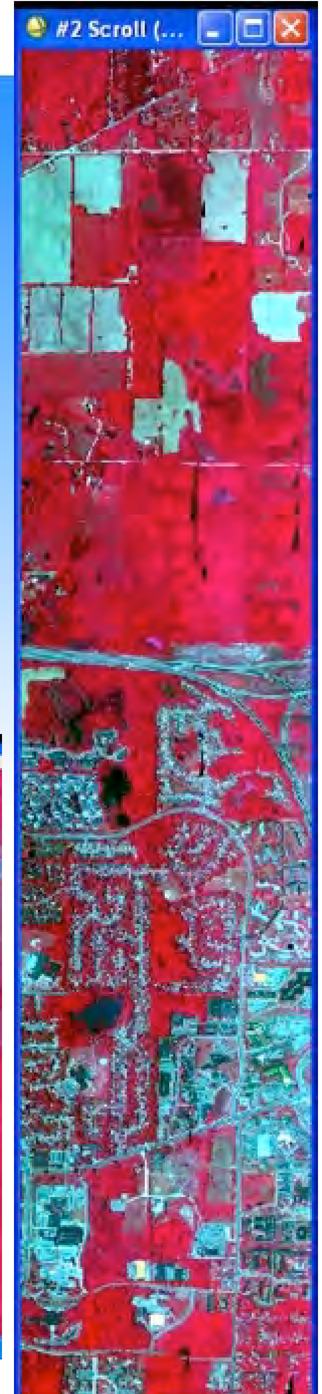
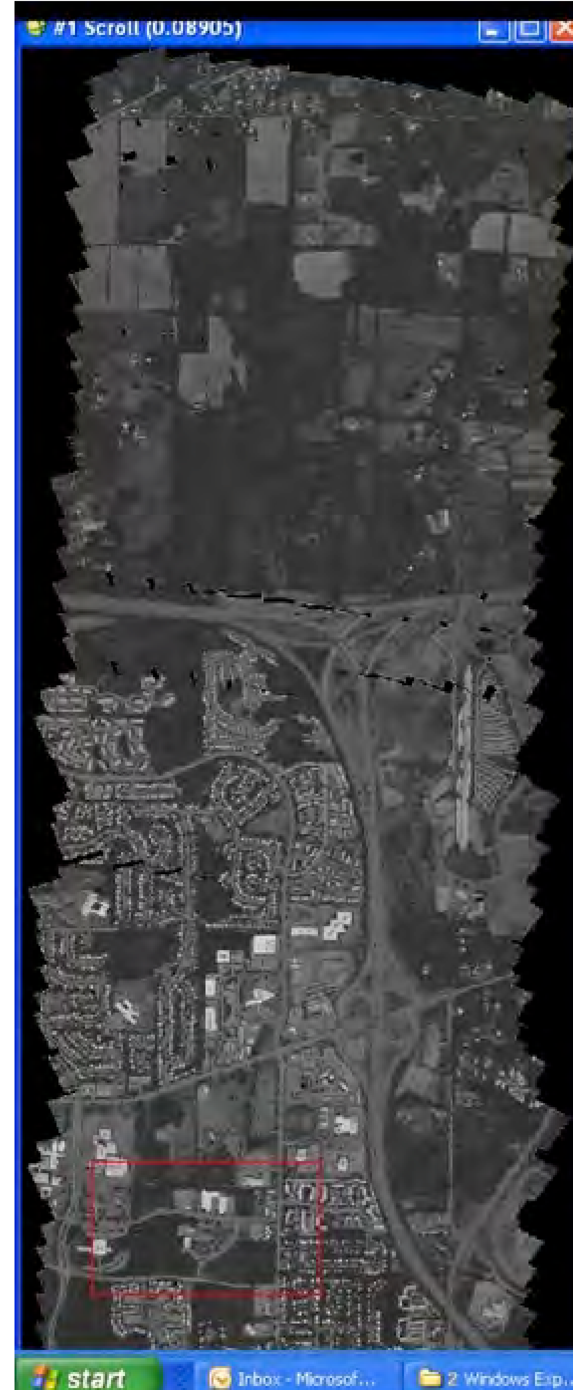
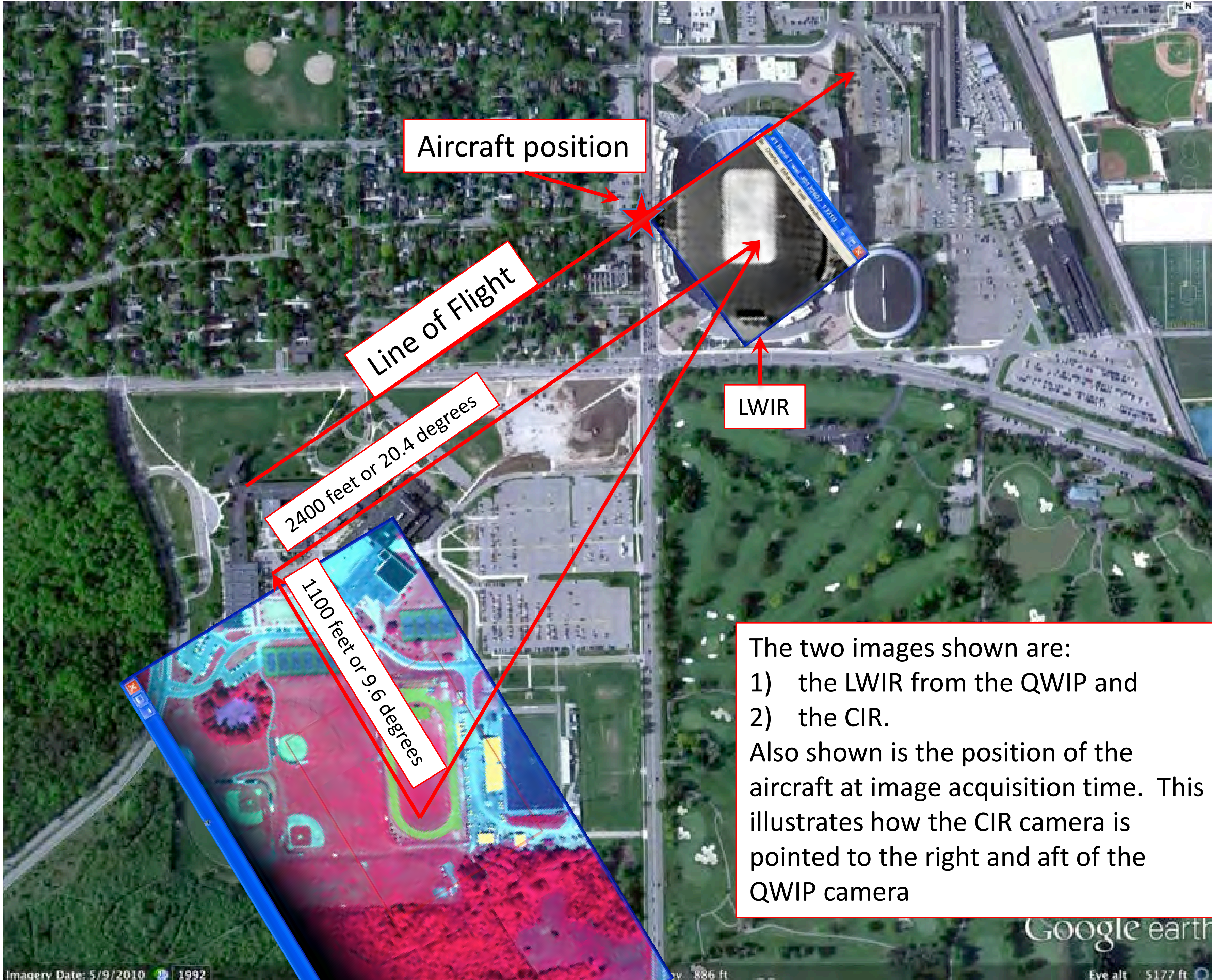
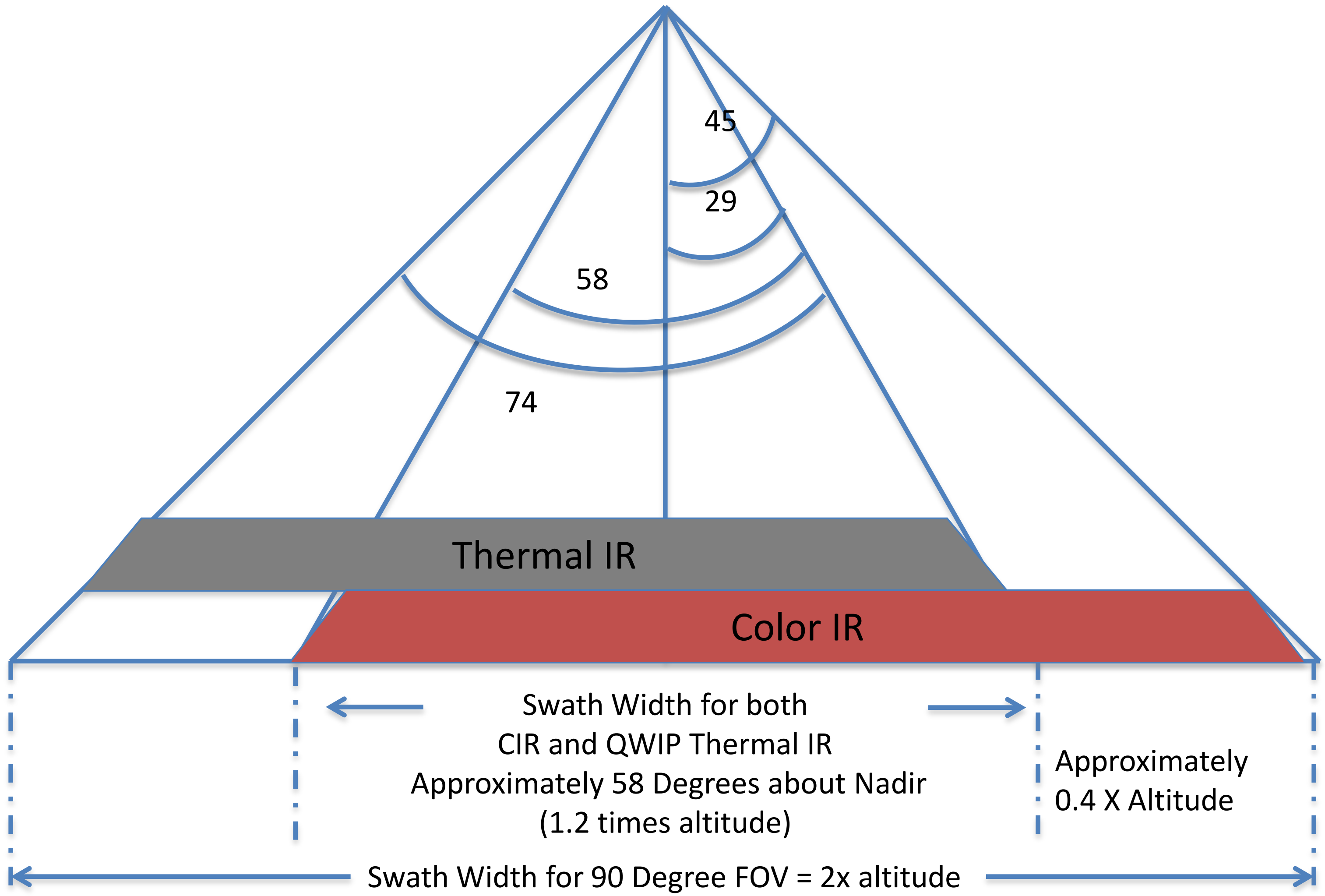


image above is composed of around 8 CIR frames






Aircraft position
Line of Flight
2400 feet or 20.4 degrees
1100 feet or 9.6 degrees
LWIR
The two images shown are:
1) the LWIR from the QWIP and
2) the CIR.
Also shown is the position of the aircraft at image acquisition time. This illustrates how the CIR camera is pointed to the right and aft of the QWIP camera
Google earth
Imagery Date: 5/9/2010
1992
886 ft
Eye alt 5177 ft



In the Parameters menu –

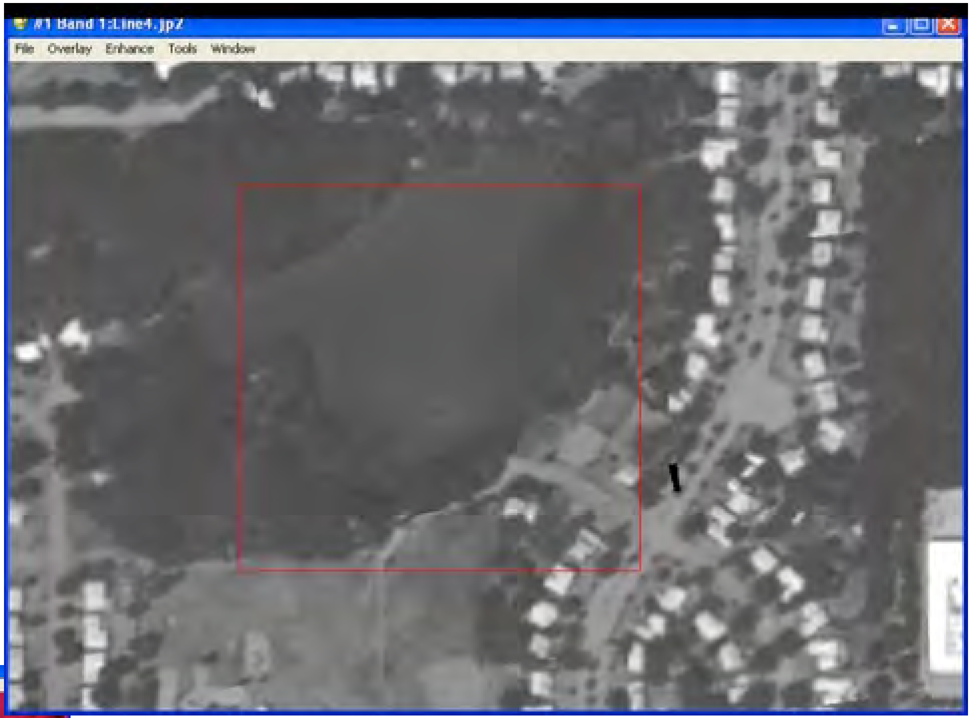
Home Offset(deg) is normally 84.20 - Change this to 100.20 (Rotates the FOV 16 degrees to the Center the CIR and Thermal IR image sets)

Set Scanner FOV(deg) to desired swath plus 16

This Illustration shows 58 degree TIR and CIR coverage with Scanner FOV(deg) set to 74 degrees

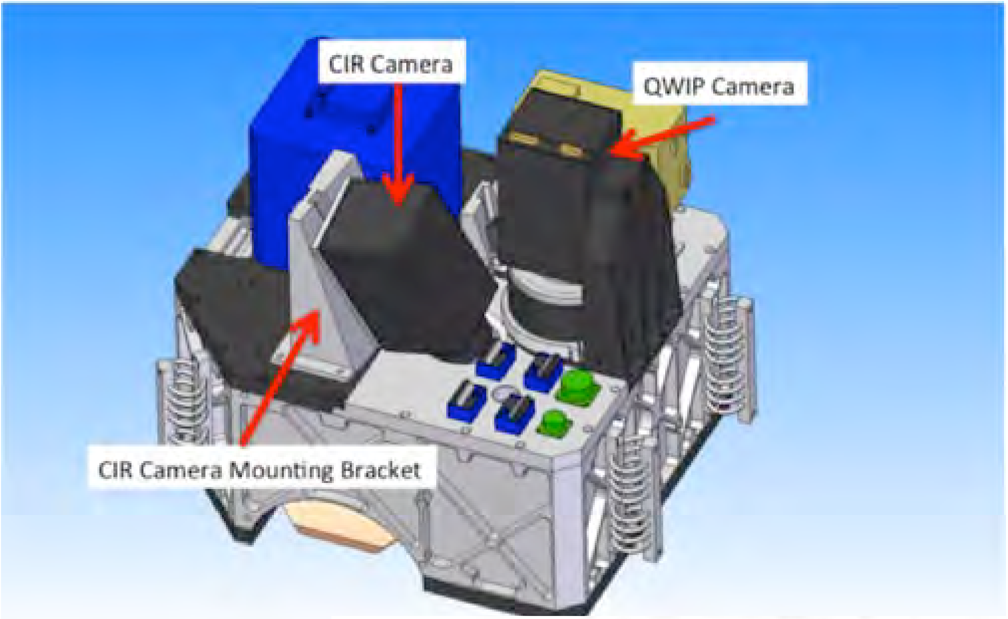
Update on the Wide Area Imager Phase III

Update on the Wide Area Imager Phase III



Update on the Wide Area Imager Phase III

Update on the Wide Area Imager Phase III



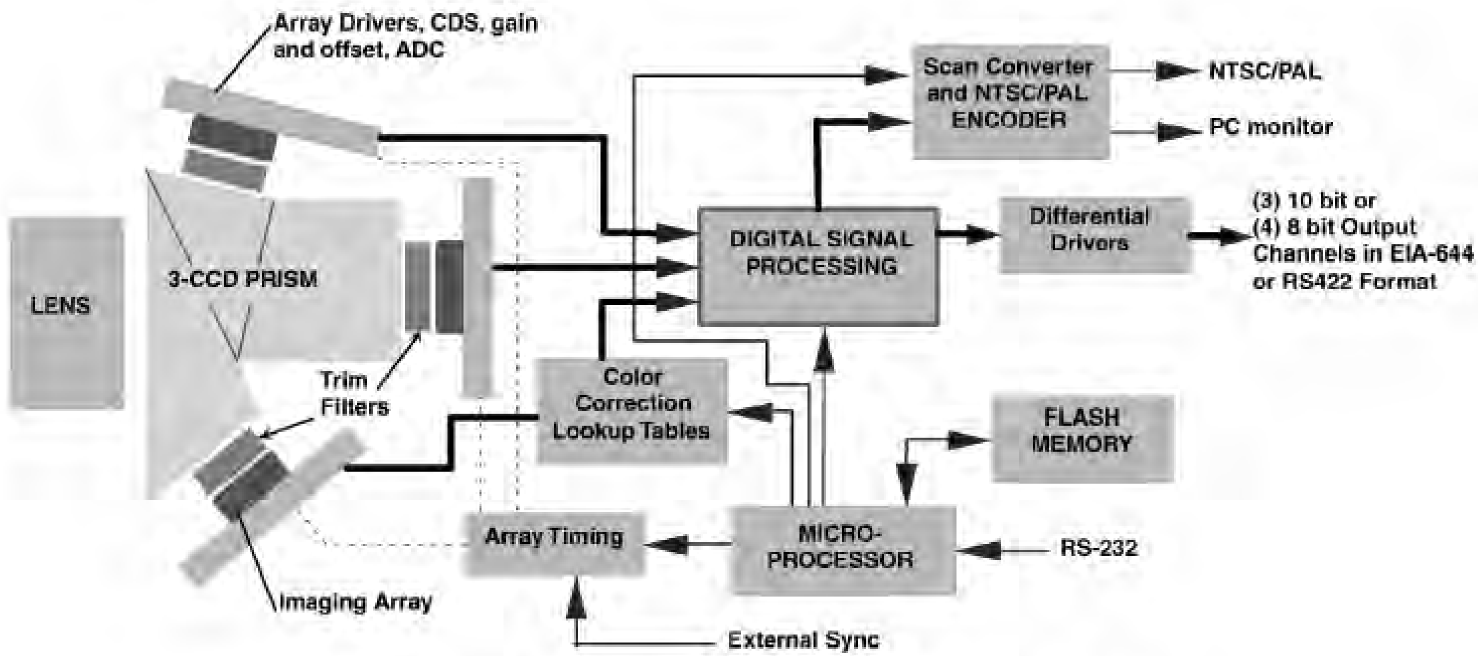


Figure 1. Functional diagram –MS4100 camera

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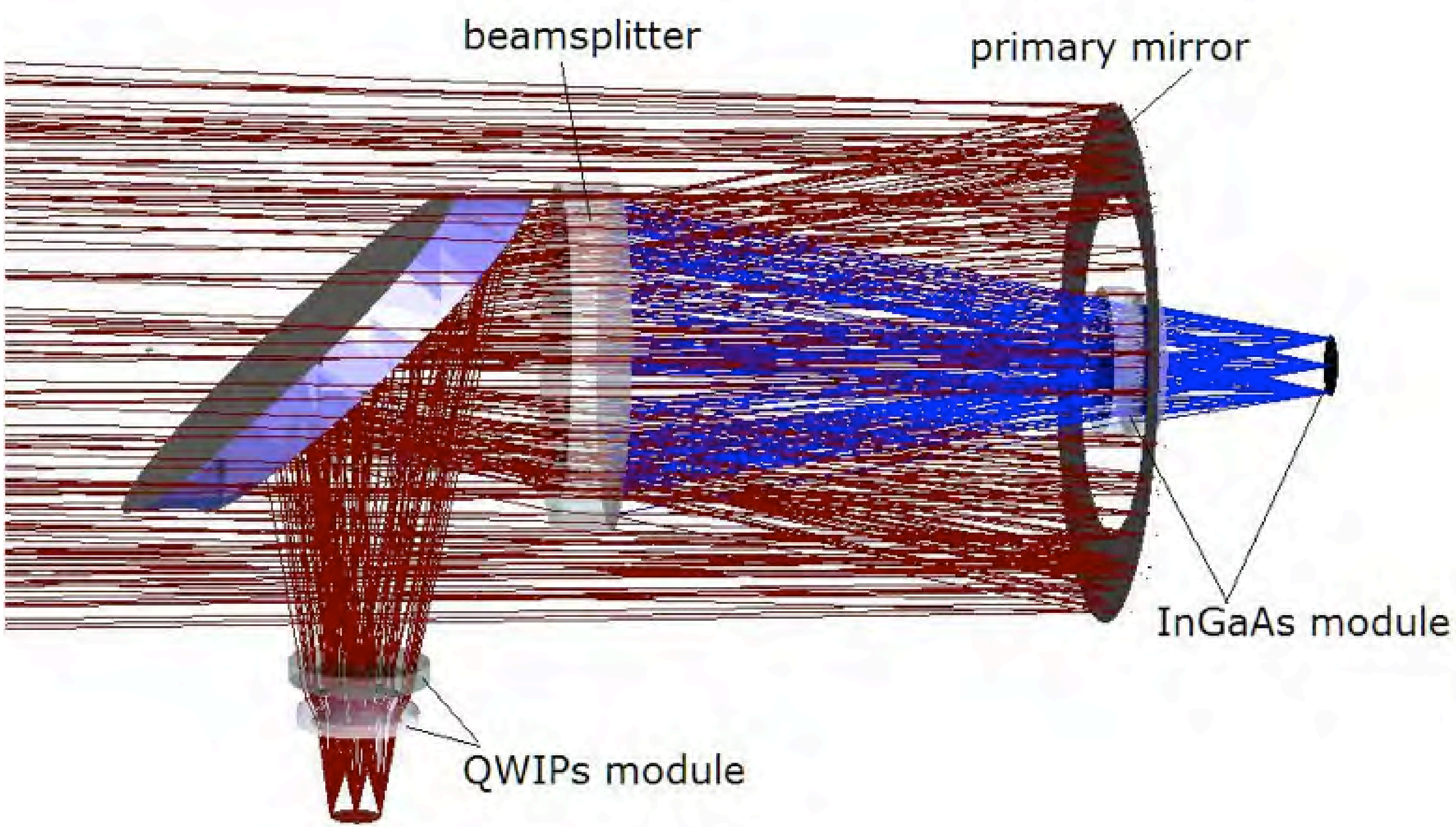
We should also note that we are in the process of designing a co-axial multi-sensor optical system for the TMAS SBIR which can be adapted for the WAI.



Vibration Testing of the WAI

Aircraft Installation at PhotoScience in Kentucky
Nov. 2012

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Wide Area Imager Fire Mapping Evaluation/Demonstration Mission – 2012/2013

Project Objective(s)

1. Multi-day evaluation and demonstration mission positioning the WAI sensor over active fires, and over previously burned areas to assess post-fire conditions.
2. High resolution CIR and Thermal IR imagery will be provided to the Forest Service for evaluation to determine utility in deriving standard tactical fire mapping/geospatial products.
3. High resolution Color Infrared imagery of post-fire areas will also be collected and provided to evaluate the sensor's ability to corroborate/validate satellite-based assessments of burn severity conducted by the Forest Service.

Place of Performance/Hours of Operation

1. The base location for the mission will be dependent on the location and numbers of current fires.
2. The duration for the proposed fire mapping mission will be three (3) days on site.
3. During this three day period, daily flight plans will be developed in coordination with the Forest Service to deploy the sensor to map as many fires as possible during daily four hour operational periods over the course of three days (12 hours total). These operational periods may occur during daytime or nighttime hours.
4. Conducted flights will not be an integrated part of operational fire mapping support provided by NIROPS. However, near contemporaneous acquisition of WAI imagery with acquired NIROPS Phoenix imagery is desirable for evaluation purposes.

Wide Area Imager Fire Mapping Evaluation/Demonstration Mission – 2012/2013

Imagery Format – JPEG 2000

Imagery Pixel Resolution – 300 uRadian – 3 foot from 10,000 foot AGL (example)

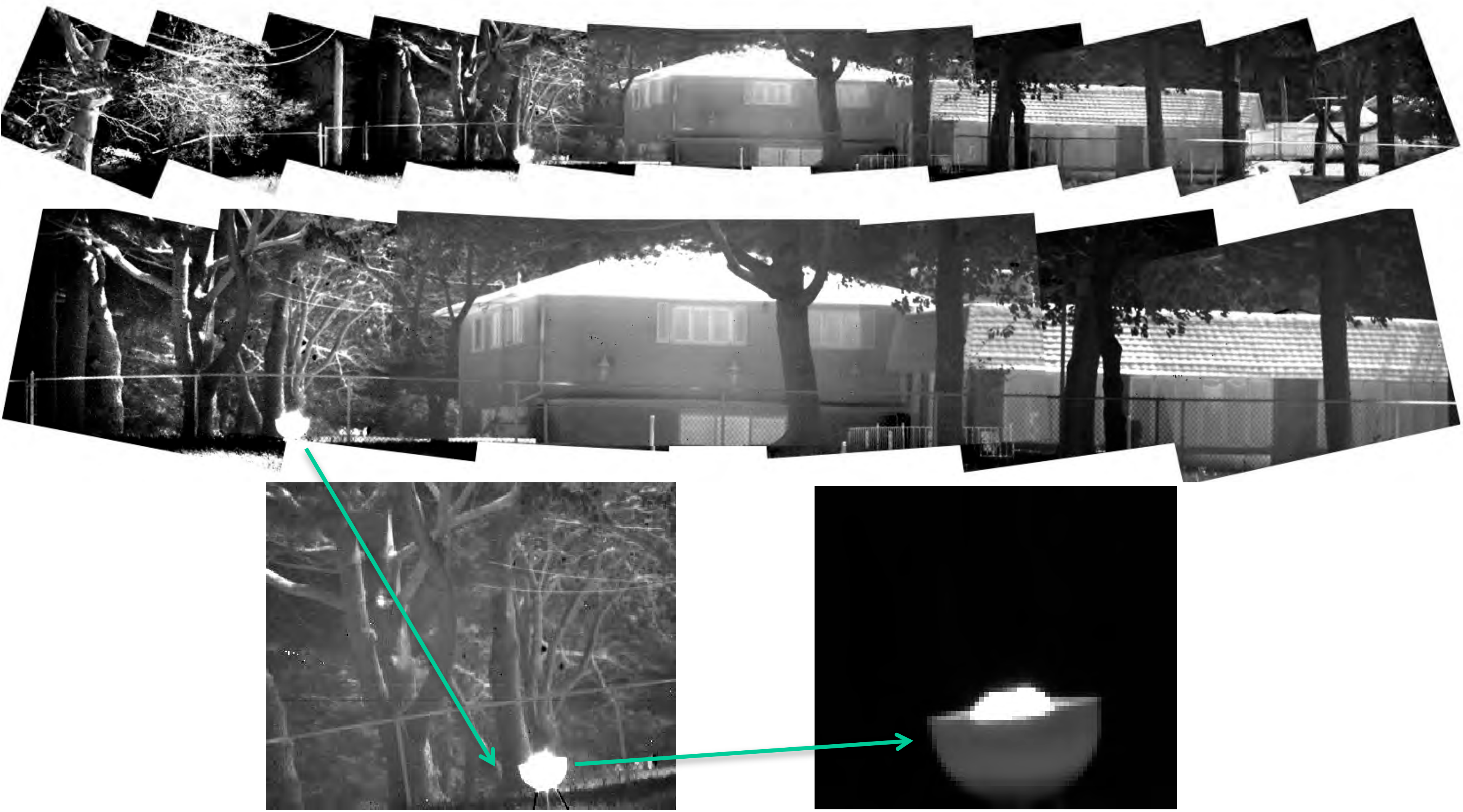
Image Geo-referencing/Projection -- Universal Transverse Mercator (UTM) projection on a WGS84 datum and spheroid, with coordinates in meters is preferred. Orthorectification to within 2 pixels at nadir is expected.

Spectral Bands -- Thermal imagery deliverables will include two bands: mid-wave (4 to 5 µm) and long-wave infrared (8 to 9 µm). Multi-spectral reflectance imagery deliverables will include three bands collected simultaneously with the thermal imagery: green (0.5 to 0.6 µm), red (0.63 to 0.69 µm) and near infrared (0.76 to 0.90 µm) bands.

Imagery Acquisition Schedule -- WAI image acquisition missions may occur during the day and/or night throughout the multi-day mission period. For daytime missions, both thermal and multi-spectral reflectance image datasets will be delivered. For nighttime missions, only the thermal imagery will be delivered.

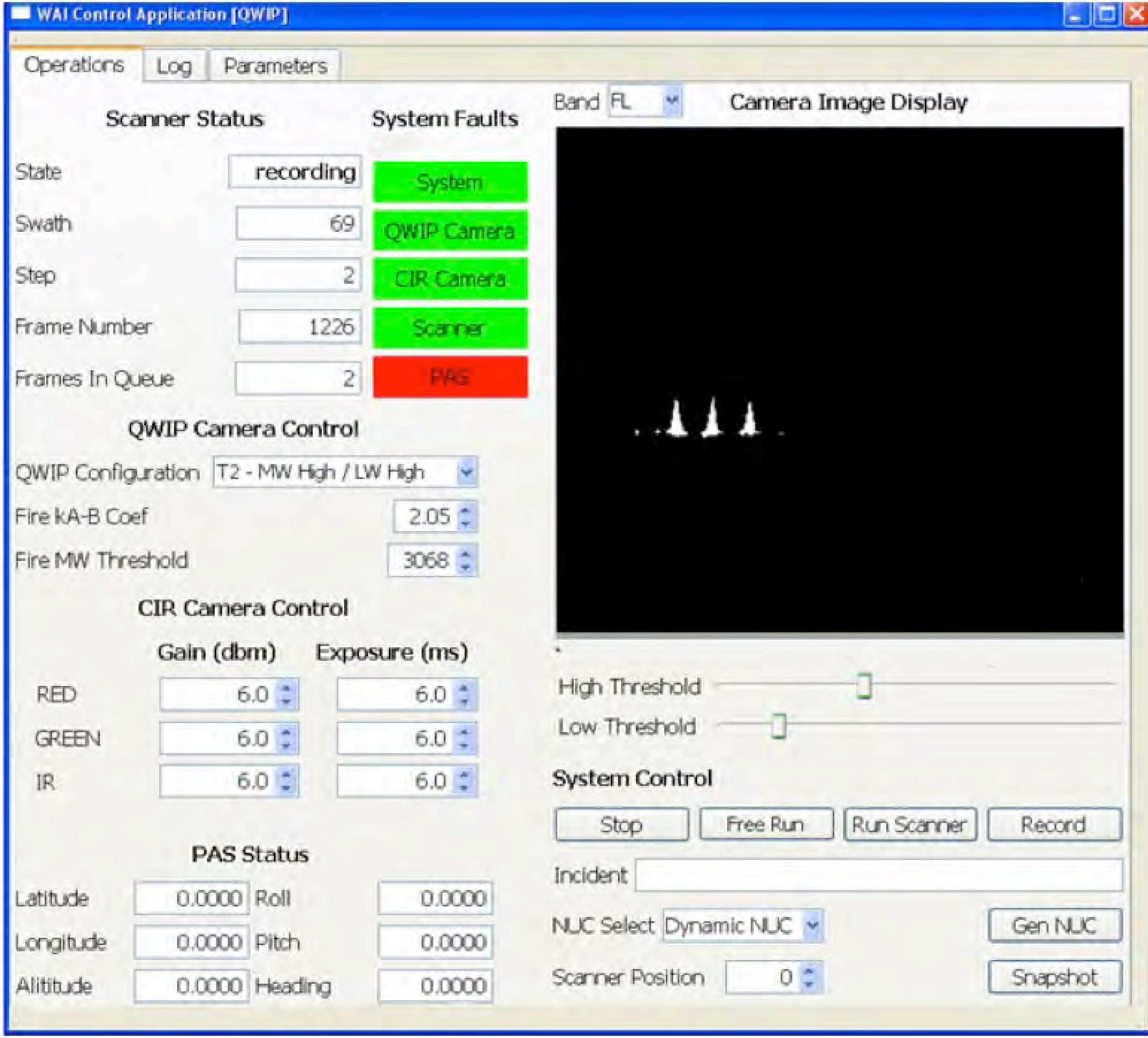
Imagery Delivery Schedule and Delivery Method -- File Transfer Protocol (FTP) or USB-enabled hard drives. Delivery of thermal imagery datasets shall occur within 6 hours of completion of each mission flight. Delivery of multi-spectral imagery datasets shall occur within 7 days of completion of each mission flight.

First imagery from the WAI



2 Point Non-Uniform Correction Applied, but
Bad Pixel Replacement has not been done


#1 Zoom [2x]
Three Fires


WAI Control Application [QWIP]
Operations
Log
Parameters
Scanner Status
System Faults
State
recording
System
Swath
69
QWIP Camera
Step
2
CIR Camera
Frame Number
1226
Scanner
Frames In Queue
2
PAS
QWIP Camera Control
QWIP Configuration
T2 - MW High / LW High
Fire kA-B Coef
2.05
Fire MW Threshold
3068
CIR Camera Control
Gain (dbm)
Exposure (ms)
RED
6.0
6.0
GREEN
6.0
6.0
IR
6.0
6.0
PAS Status
Latitude
0.0000
Roll
0.0000
Longitude
0.0000
Pitch
0.0000
Alititude
0.0000
Heading
0.0000
Band
FL
Camera Image Display
High Threshold
Low Threshold
System Control
Stop
Free Run
Run Scanner
Record
Incident
NUC Select
Dynamic NUC
Gen NUC
Scanner Position
0
Snapshot

NASA SBIR/STTR Technologies

Airborne Wide Area Imager for Wildfire Mapping and Detection

Contract No. NNX09CA09C

PI: John M Green
Xiomas Technologies

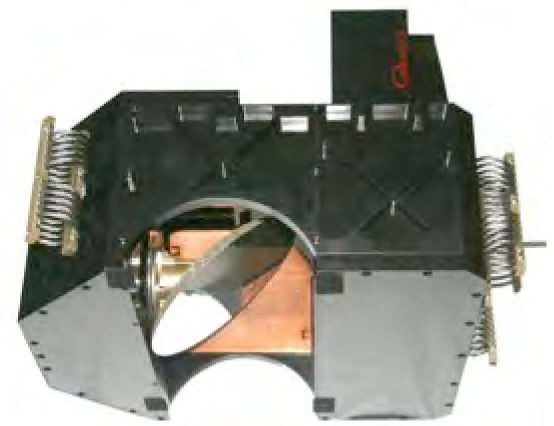
Identification and Significance of Innovation

An autonomous airborne imaging system for earth science research, disaster response, and fire detection is proposed.

The primary goal is to improve information to researchers and operations personnel at reduced cost. By operating autonomously and with higher spatial resolution, the system will deliver a 3X to 4X reduction in operating costs compared to current systems.

The system uses a two color Quantum Well Infrared Photo detector (QWIP) to improve the accuracy of energy release from wildfires, thereby improving our understanding of the carbon cycle.

Expected TRL Range at the end of Contract (1-9): 7



Xiomas Wide Area Imager Sensor Head

Technical Objectives and Work Plan

1) Detect 8-inch diameter, 600°C hot spots, while imaging the day and night ground terrain through smoke from an altitude of 30,000 to 40,000 feet.
2) Generate fuel loading and burn area classification maps.
3) Locate the image pixels to a map accuracy of 10 meters.
4) Image terrestrial features with dimensions of around 2 meters in order to observe natural and man-made fire barriers.
5) Transmit geometrically corrected and classified imagery in near real time to a centralized spatial data base.
6) The airborne system must be capable of autonomous or remote operation.
7) The airborne instrument must small enough for light aircraft or UAV installations

NASA and Non-NASA Applications

NASA:
•Unmanned Airborne System and Sensor Development
•Fire Detection and Mapping Research
•Research into the Development of Automated Sensors
•Carbon Cycle Research
US Forest Service:
•Reduced cost of National Infrared Operations
•Real Time Fire Detection and Mapping
DHS:
•Disaster Response
•Border Patrol

Firm Contacts

John M. Green johngreen@xiomas.com
1317 Skyway Drive
Ypsilanti, MI
48197
734-646-6535

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NON-PROPRIETARY DATA

TMAS
Thermal Mapping Airborne Simulator
for
Small Satellite Sensor

Phase I

February 2012

NASA Proposal Number – S1.08-8082

Technical Monitor James Brass

Xiomas Technologies, L.L.C.

Phase I Contract Number: NNX12CD20P

Principle Investigator: John Green
734-646-6535

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Background and Rationale –

ASTER has a smaller field of view than MODIS, viewing a swath width of 60km.

To scan any point on earth, tilt-able telescopes are employed for ASTER.

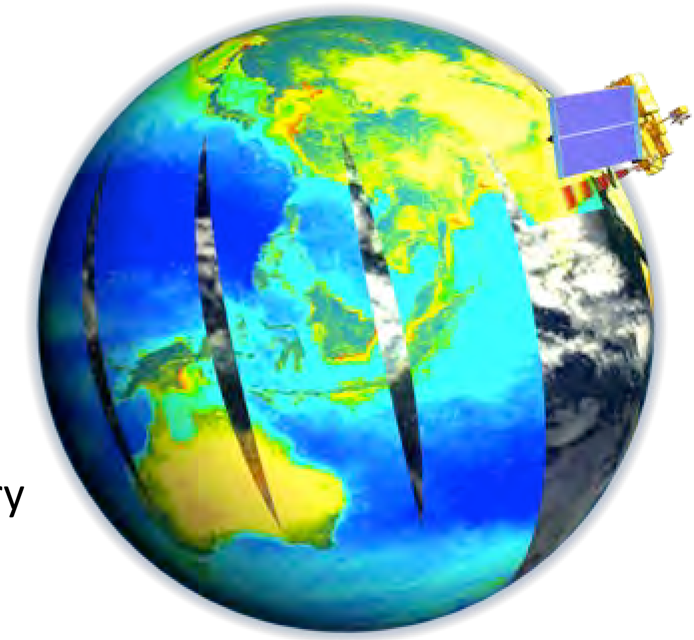
ASTER Spectral -- five spectral bands in the 8 to 12 um range.

ASTER Spatial -- The ASTER thermal infrared subsystem has a spatial resolution of 90m

The ASTER instrument operates for a limited time during the day and night portions of an orbit. The full configuration (all bands plus stereo) collects data for an average of 8 minutes per orbit. Reduced configurations (limited bands, different gains, etc.) can be implemented as requested by investigators.

TMAS
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)

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

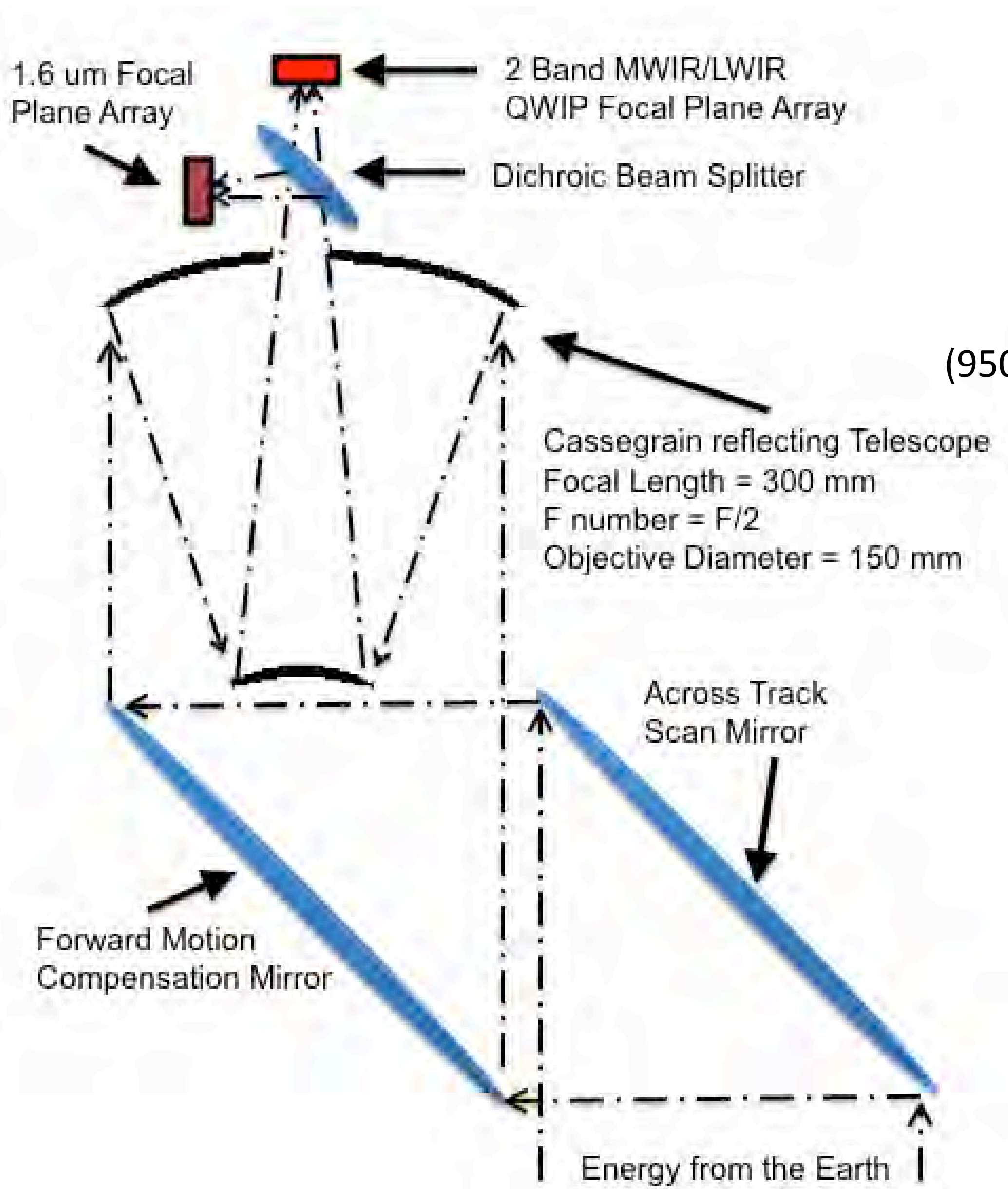


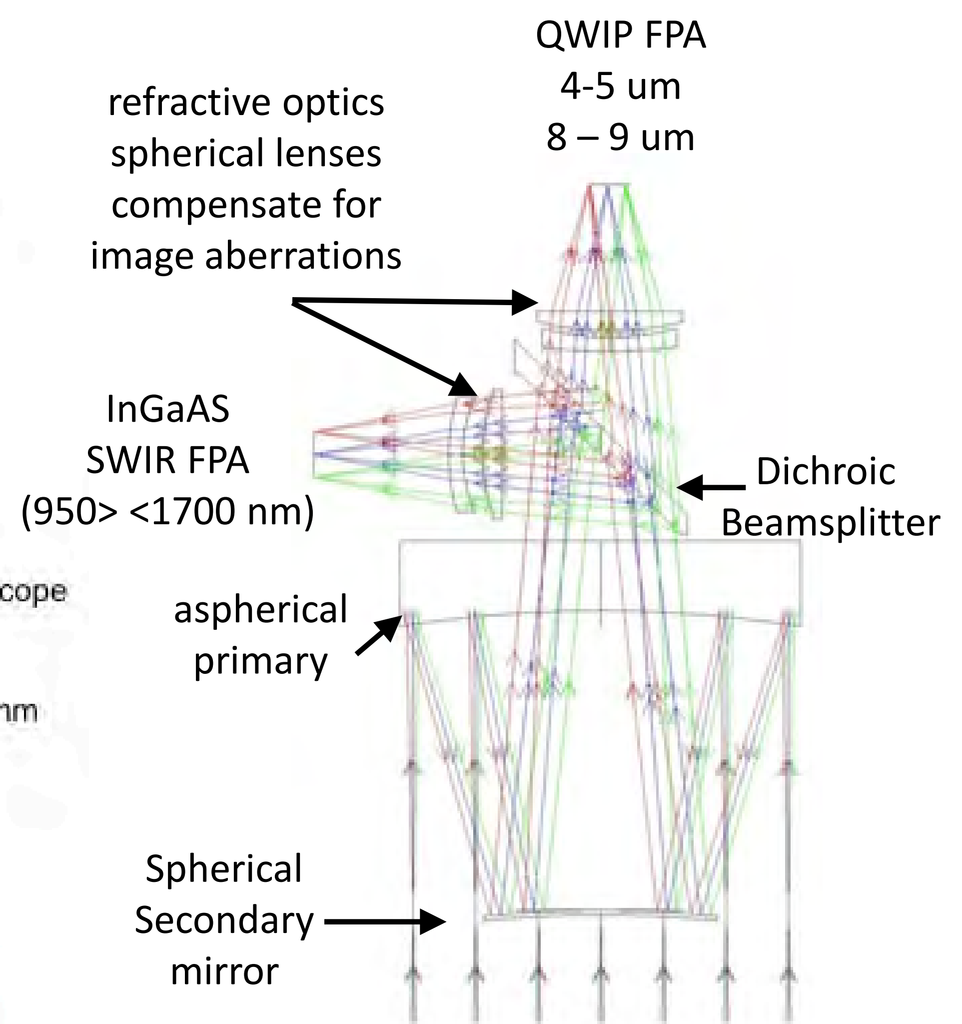
Phase I engineering prototype:

- XVME-6300 processor board with dual core i7 @ 2GHz, 8GB RAM
- Intel 64GB SSD with 3Gb/s SATA interface. Formatted as EXT4 file system
- WD 256GB SSD with 3Gb/s SATA interface. Formatted as EXT4 or JFS file systems.
- EDT PMC DV C-Link frame grabber
- Teli 640 x 480 camera

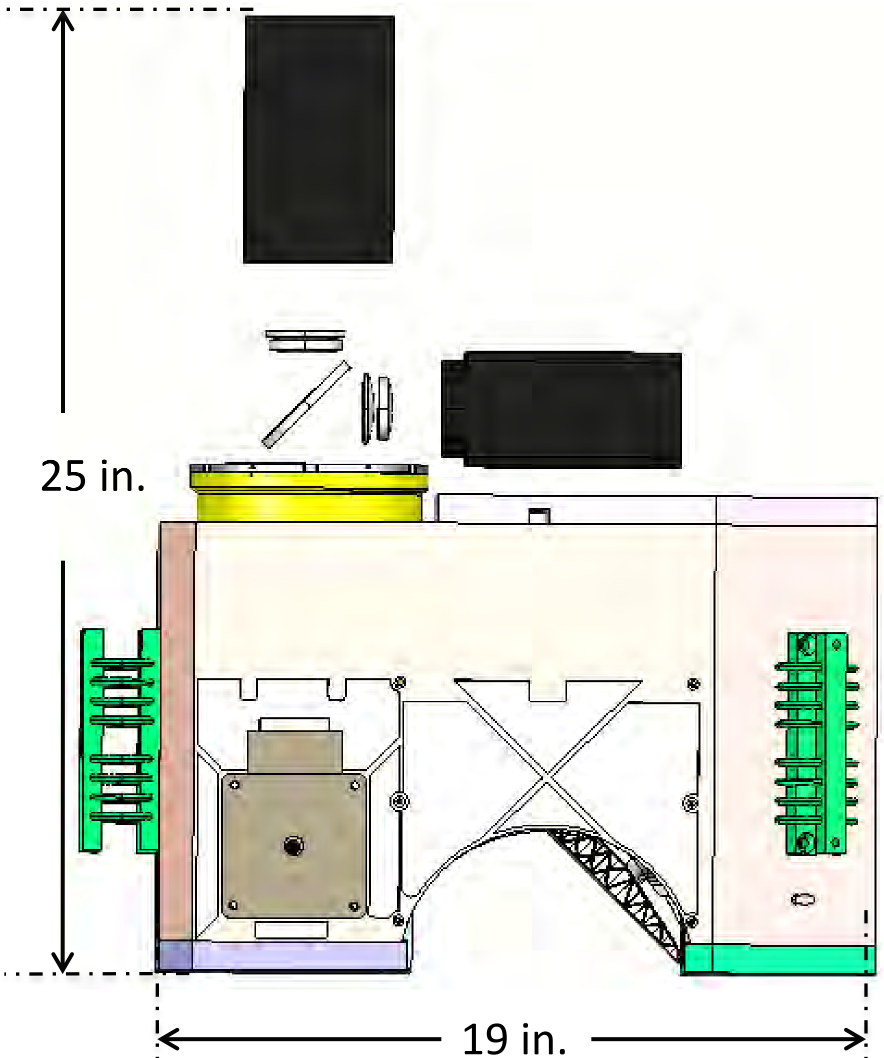
1. Simulate the data rates of the two cameras
2. Simulates a GigE QWIP, with the simulation running on another PC and connected over a 1000BaseT wire
3. Simulate SWIR sensor using CameraLink frame grabber and a 640 x 480 Vis Camera

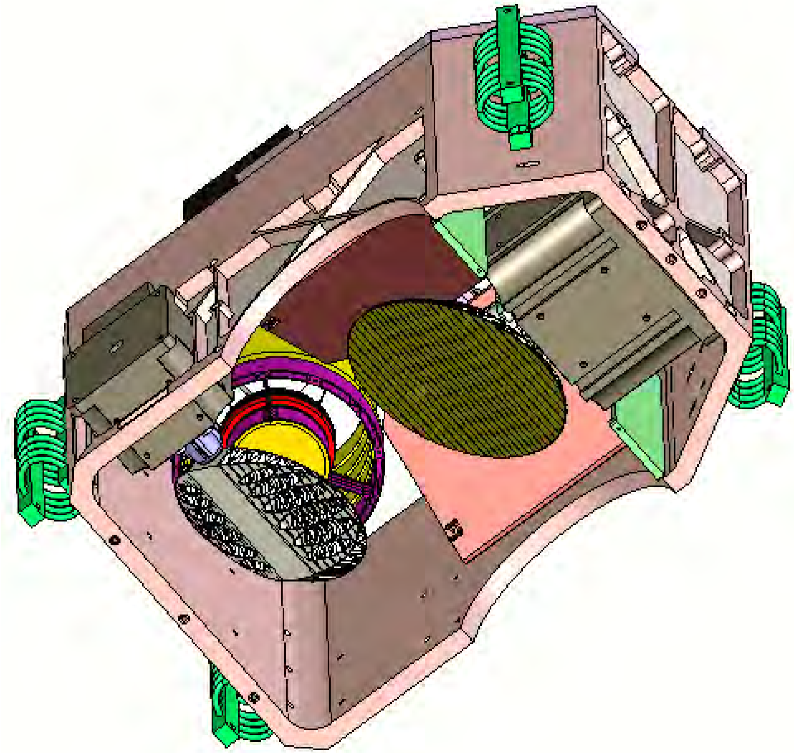
Optical Design

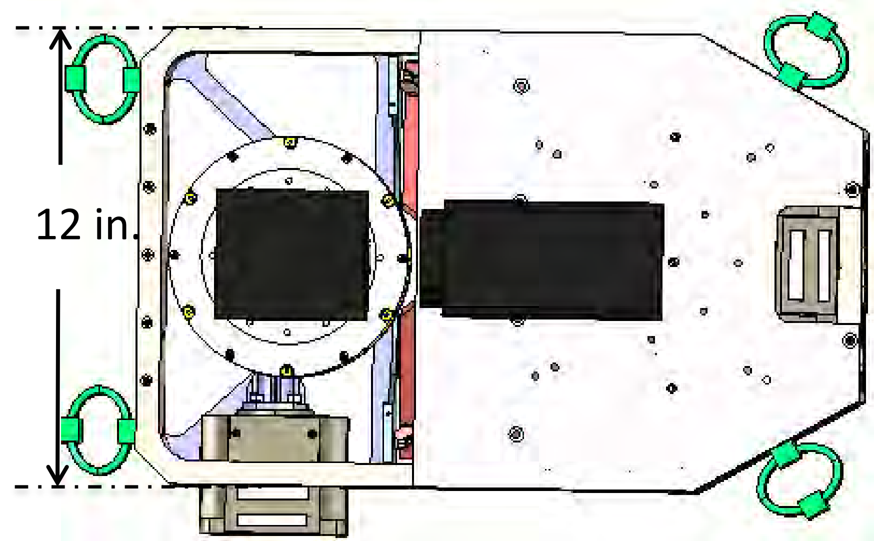


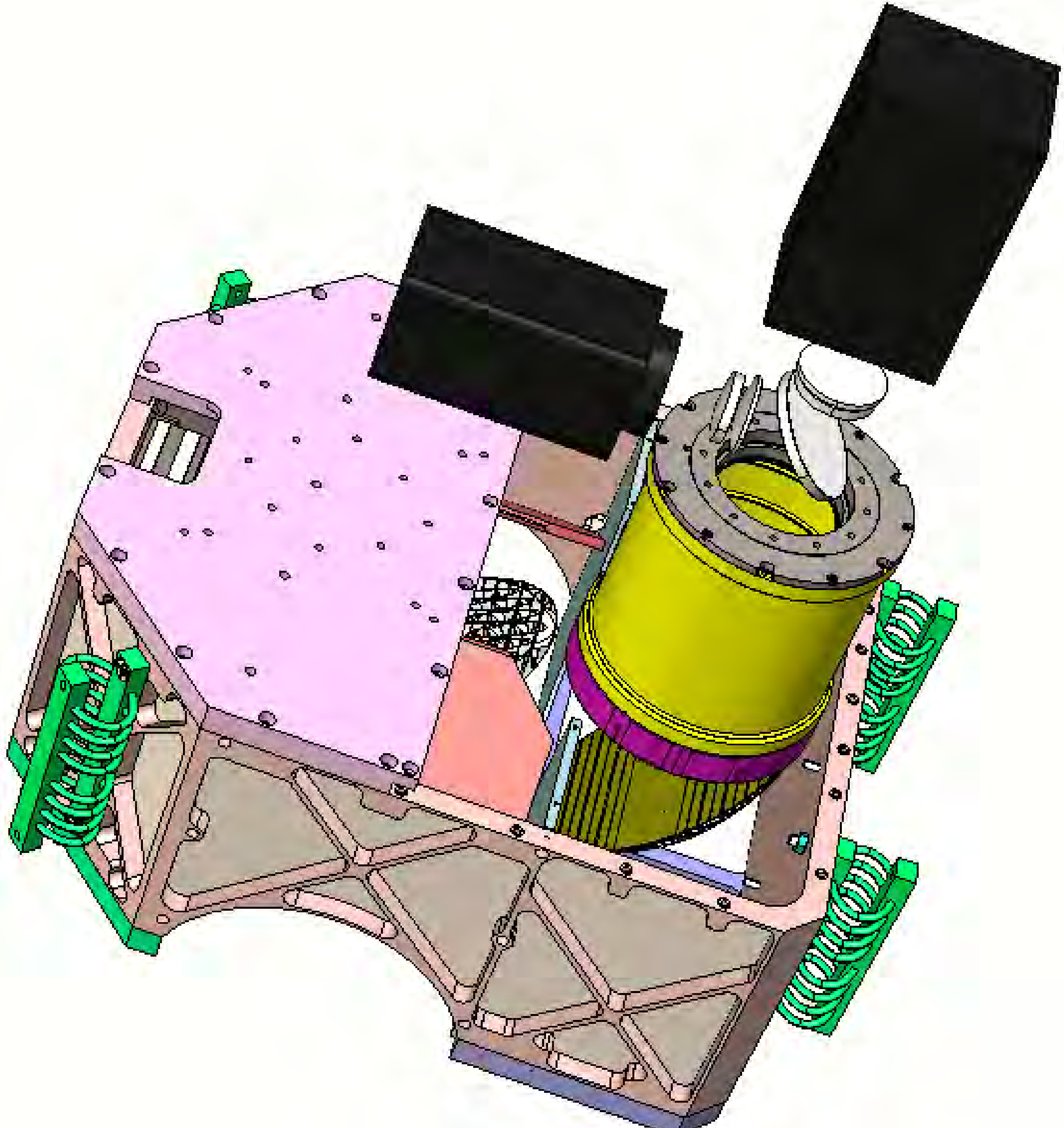


Dall-Kirkham Cassegrain


25 in.
19 in.

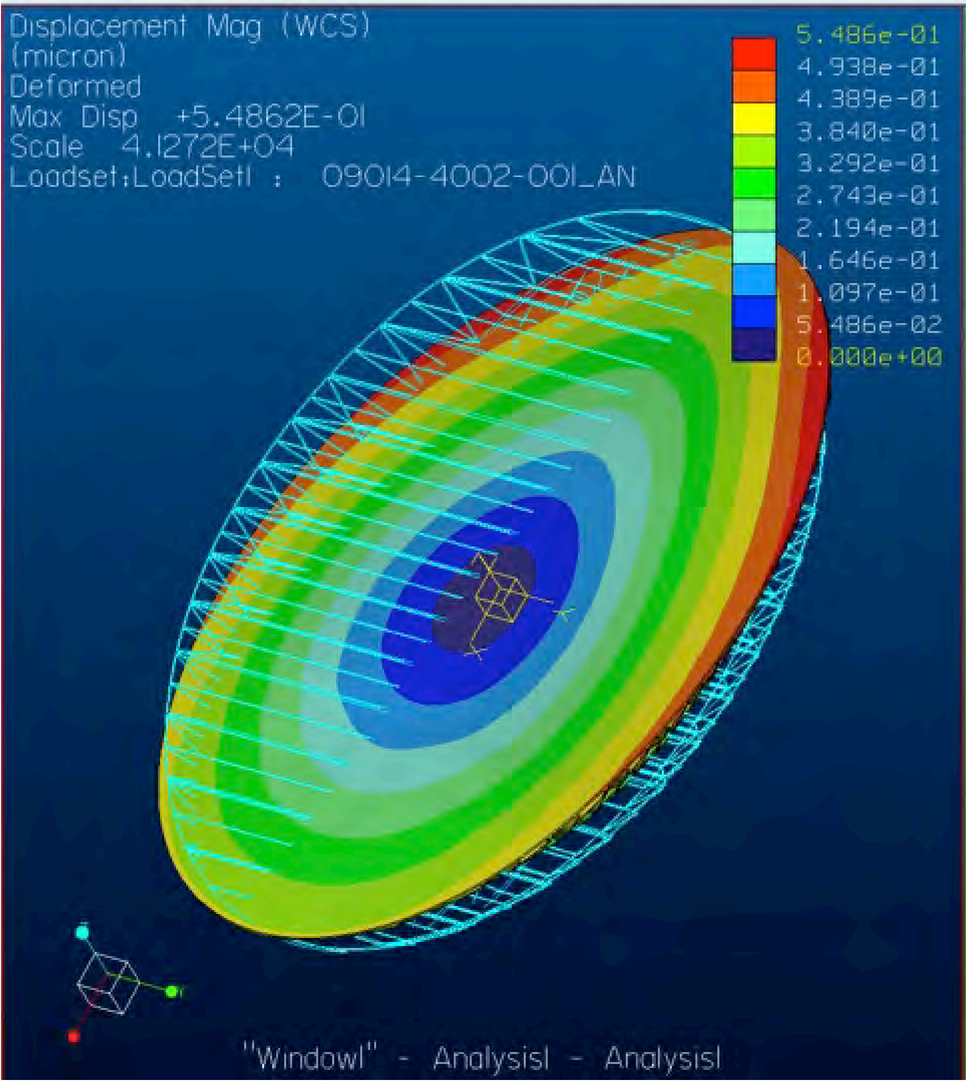


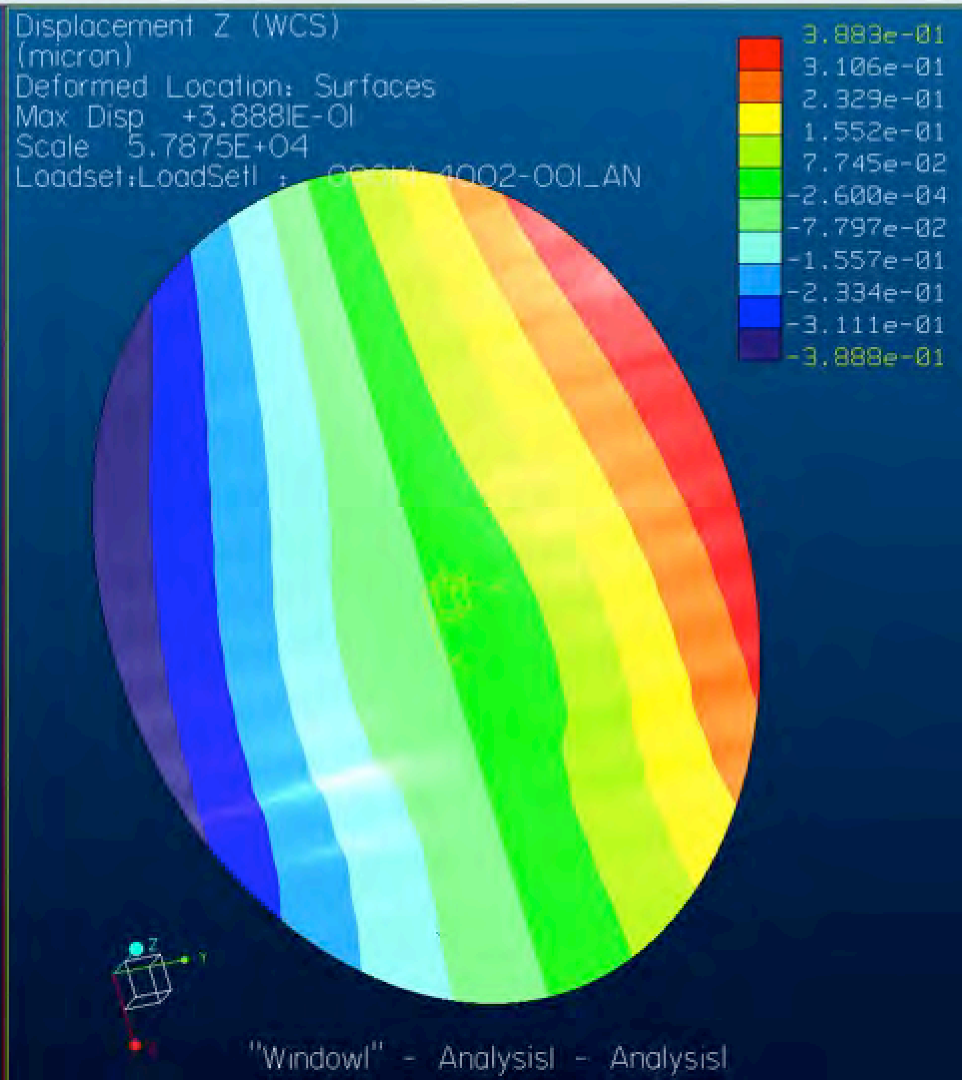

12 in.

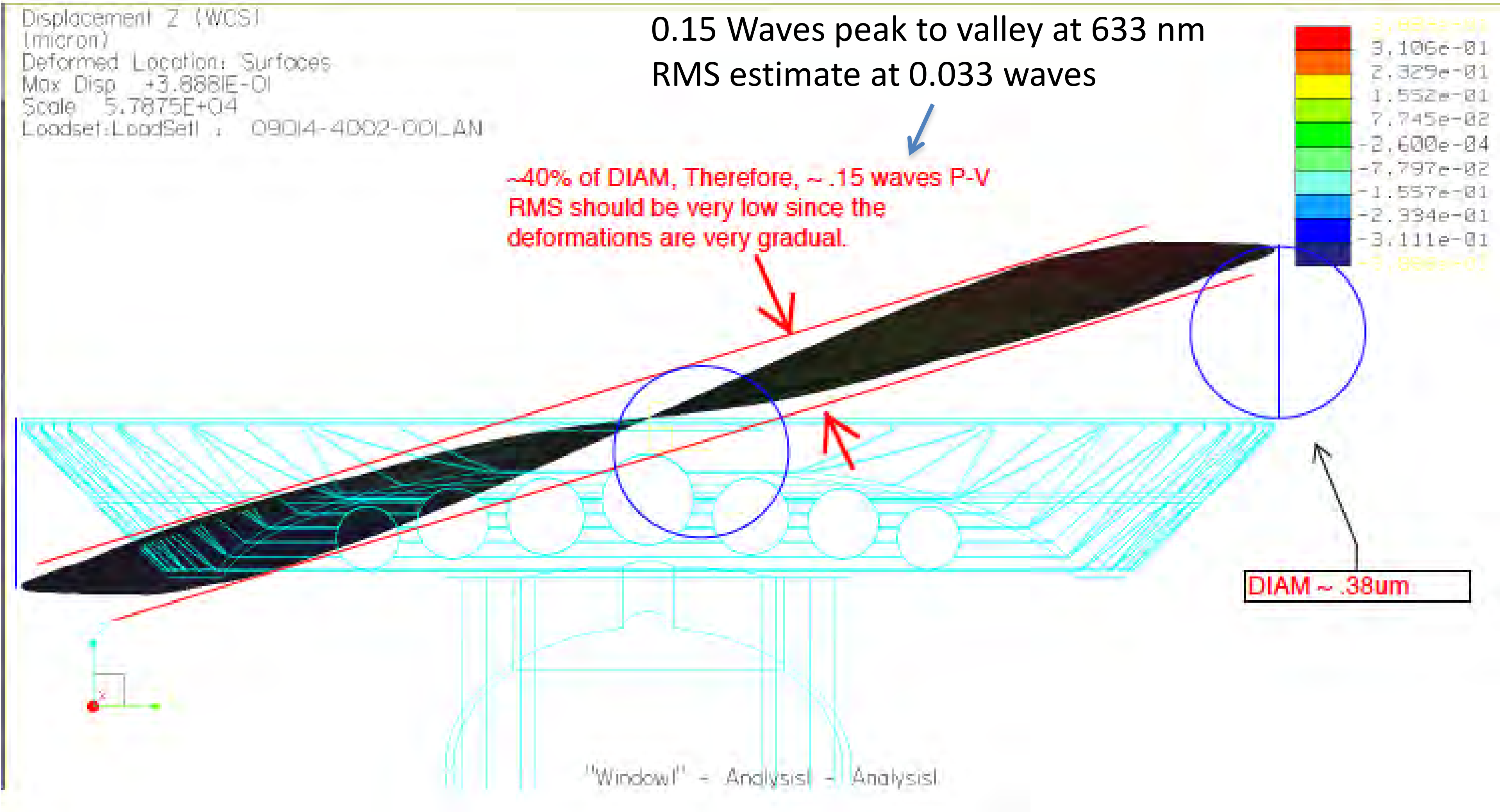


The following two slides show a dynamic mechanical analysis of the TMAS mirror design. It is critical that the mirrors remain flat and stable during the rapid step stare motion.

The goal of this analysis is to determine how the mirrors will behave given the motion profile of the scanner.







Conclusion – The mirrors remain very stable!

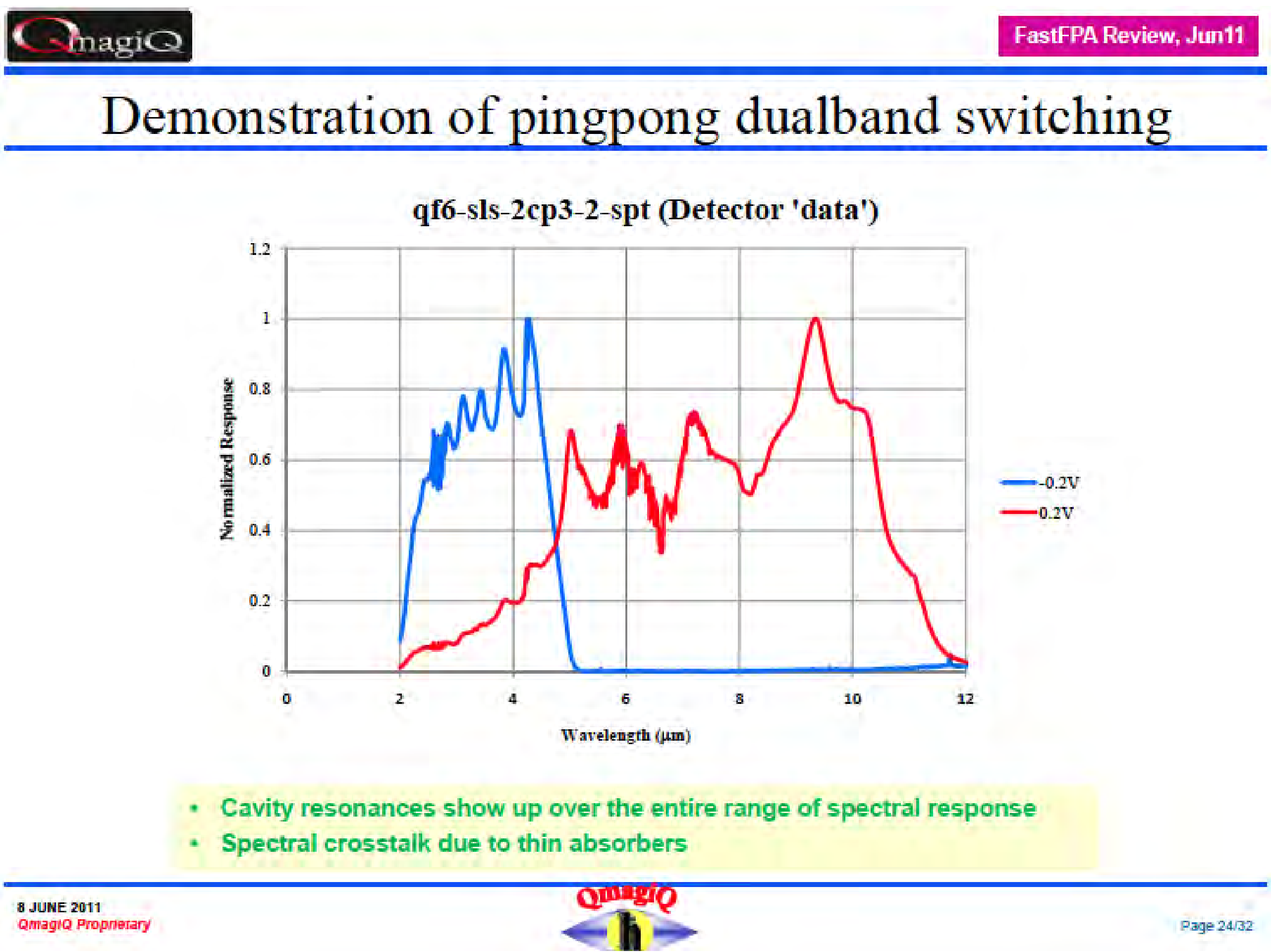
one more thing …

There are a number of ways to increase the performance of the TMAS in Phase III

1.The SWIR port can use a multi-CCD camera providing 3 bands

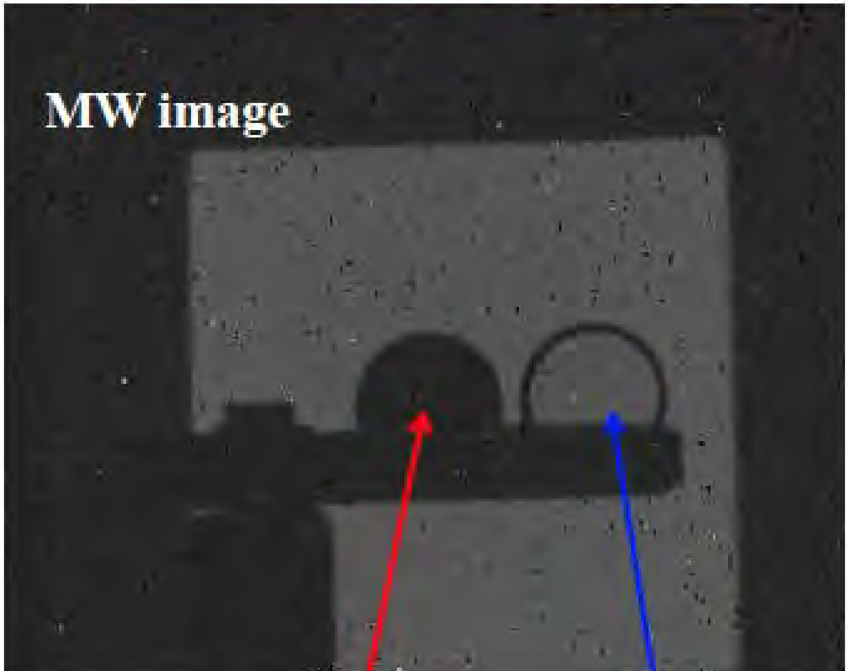
2.We can add a dichroic and include a multi-CCD Vis NIR port with 3 to 5 bands

3.A 2 band Type-II InAs/(In)GaSb strained layer superlattice (SLS) Focal Plane Array (FPA) currently in an advanced stage of development at QmagiQ. (Note that Xiomas and QmagiQ have partnered on other projects including the Xiomas WAI, TMAS, StareWAI, and HyWAI, and QmagiQ is building the QWIP FPA for the Landsat Continuity Mission).



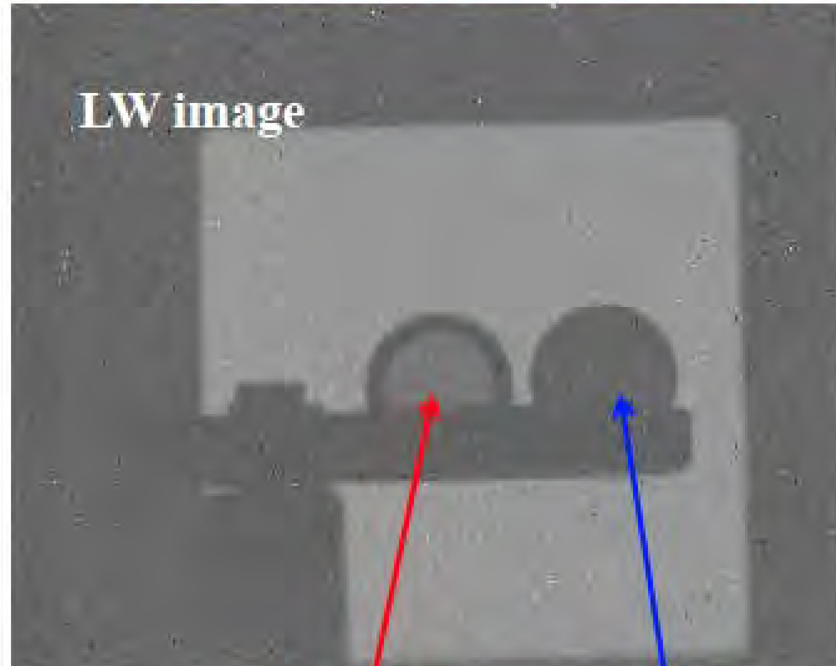
Dualband images

ISC-0903 in p-on-n mode



Red filter Blue filter

ISC-0903 in n-on-p mode



Red filter Blue filter

- Blue filter: MW pass-band (from 3.3 µm to 5.8 µm)
- Red filter: LW pass-band (from 7.4 µm to 9.5 µm)

NASA SBIR/STTR Technologies

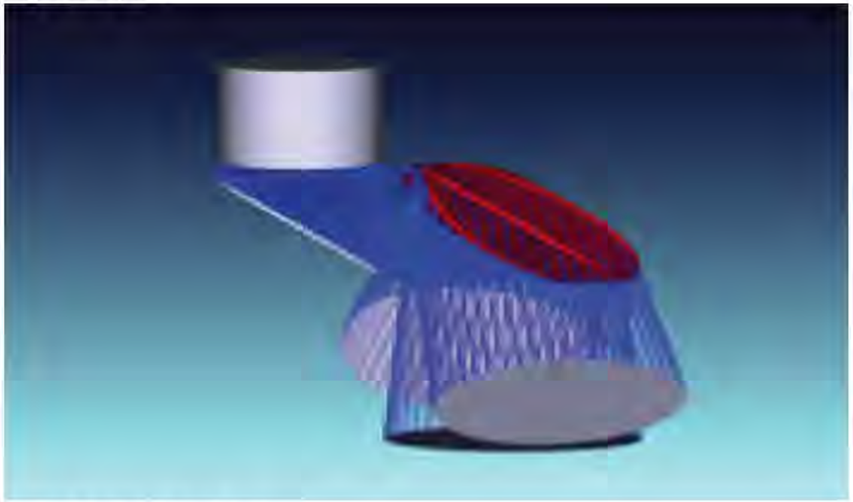
S1.08-8082 - Thermal Mapping Airborne Simulator for Small Satellite Sensor

PI: john green
Xiomas Technologies - Ypsilanti, MI

Identification and Significance of Innovation

Currently global mapping of thermal anomalies is performed by satellite based imagers operating in low earth sun-synchronous orbit, most notably the MODIS and ASTER imagers on board the satellites, Terra and Aqua.

We propose to develop the Thermal Mapping Airborne Simulator (TMAS) with the high revisit rate of MODIS but with the spatial resolution of ASTER, and have based our notional design on a 110 degree field of view (like MODIS) and a 94 meter spatial resolution (close to ASTER). 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 providing the high revisit rate of MODIS and the high spatial resolution of ASTER.



Estimated TRL at beginning and end of contract: (Begin: 2 End: 4)

Technical Objectives and Work Plan

The overall objective of the SBIR is to develop a high performance, inexpensive, airborne simulator that will serve as the prototype for a small satellite based imaging system capable of mapping thermal anomalies on the surface of the earth with a high revisit rate and high spatial resolution. The Thermal Mapping Airborne Simulator for Small Satellite Sensor will be developed to a TRL 8 in the Phase II and the space-qualified system will be developed and built in Phase III.

The proposed system will deliver high spatial resolution, high signal to noise performance, two or three spectral bands, and onboard processing to extract the information of greatest value, orthorectify the imagery, and reduce the size of the data for transmission. This sensor system is designed to fit within the size, weight, and power (SWaP) envelopes of typical remote sensing aircraft and small satellites.

For this proposal we have developed a notional design that will be reviewed and further developed during the Phase I. The proposed design incorporates a step stare scanning mirror, a two band (LWIR 8 to 9 um and MWIR 4 – 5 um) Quantum Well Infrared Photodetector (QWIP), a short wave IR sensor (1.6 um), and an FPGA based image processing and orthorectification processing module.

NASA Applications

the TMAS prototype delivered in the Phase II will be the most advanced airborne system of it's type in both the civilian and defense worlds. In addition to the primary role as a prototype for the small satellite sensor, significant interest exists in wildfire science, wildfire detection and mapping, volcanology, oil spill detection and mapping, and mapping of large for thermal anomalies in general

Non-NASA Applications

In addition to the primary role as a prototype for the small satellite sensor, the TMAS is of interest to other U.S. government agencies including: Departments of Energy (especially NA22 Nuclear Non-Proliferation), Agriculture (Forest Service), Border Patrol, and Defense.

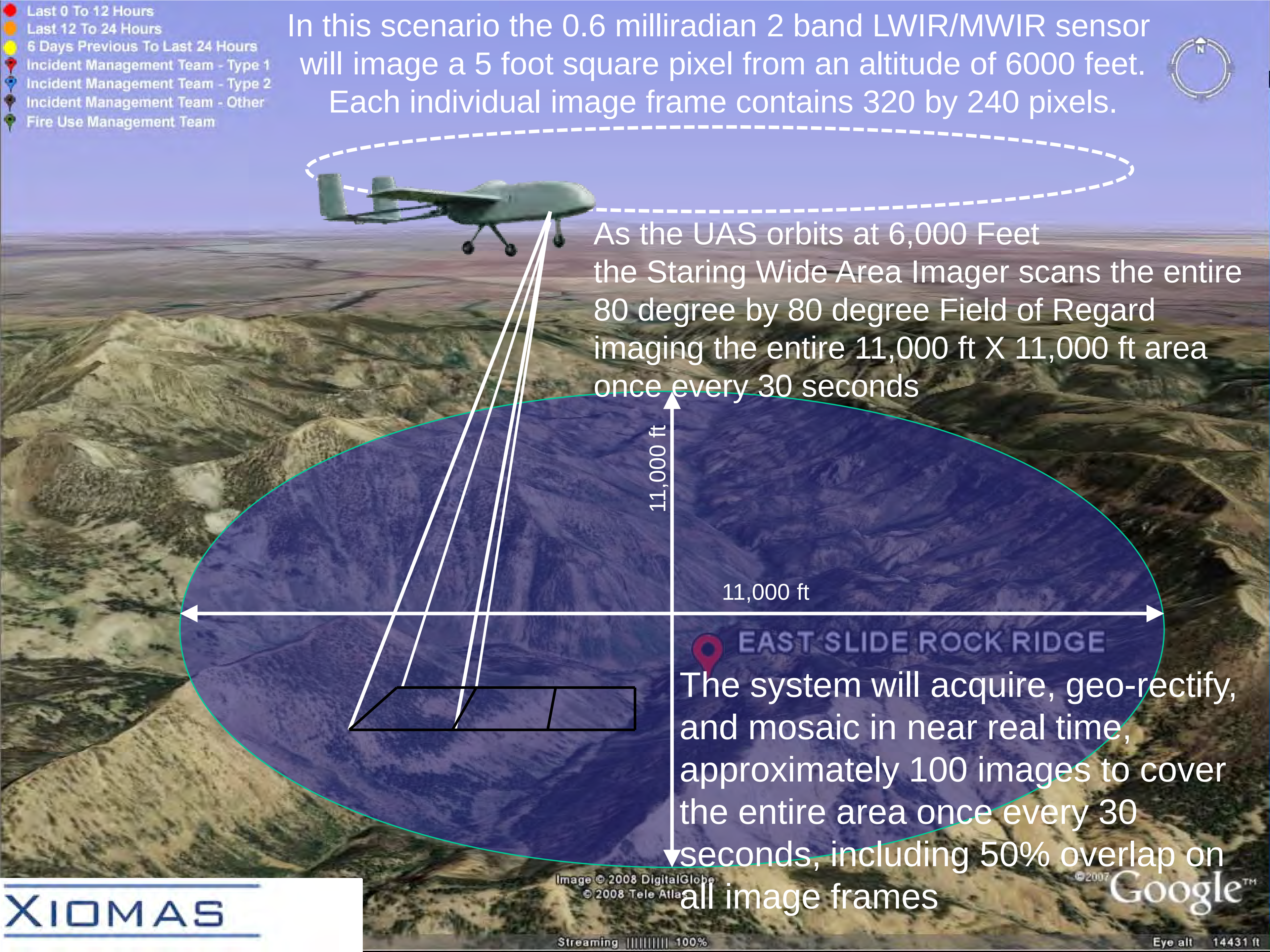
Firm Contacts

john green
Xiomas Technologies
1317 Skyway Drive
Ypsilanti, 481978952
PHONE: (734) 646-6535
FAX: () -

Staring Wide Area Imager
(STAREWAI)

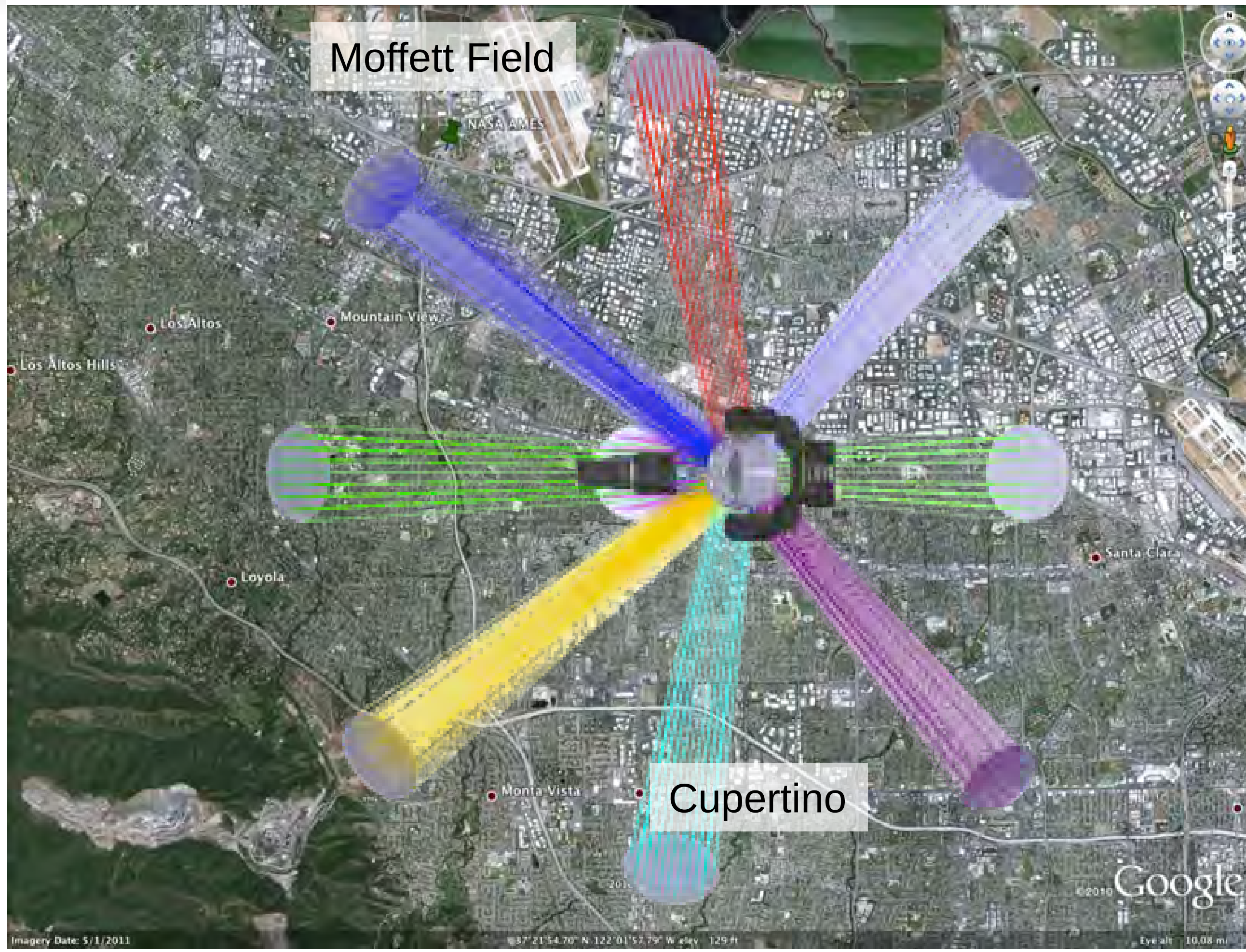
USDA Phase I SBIR
Contract Awarded
Start Date May 2012

Xiomas Technologies, L.L.C.


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

In this scenario the 0.6 milliradian 2 band LWIR/MWIR sensor will image a 14 foot square pixel from an altitude of 23,000 feet. As the aircraft orbits at 23,000 Feet the Staring Wide Area Imager scans the entire 80 degree by 80 degree Field of Regard, imaging the entire 9 mile diameter area once every 30 seconds -- acquiring, geo-rectifying, and mosaicking in near real time, approximately 100 images to cover the entire area once every 30 seconds. This calculation includes 50% overlap on all image frames

- LWIR (8 to 9 um)
- MWIR (4 – 5 um)
- SWIR 1.6 um (optional)
- 600 urad instantaneous field of view
- ground sample distance of approximately 14 feet from our notional operating altitude of 23,000 feet.
- At this altitude the system will be capable of detecting a 6 inch by 6 inch 600 degree C fire.
- 9 Mile Diameter Field of Regard



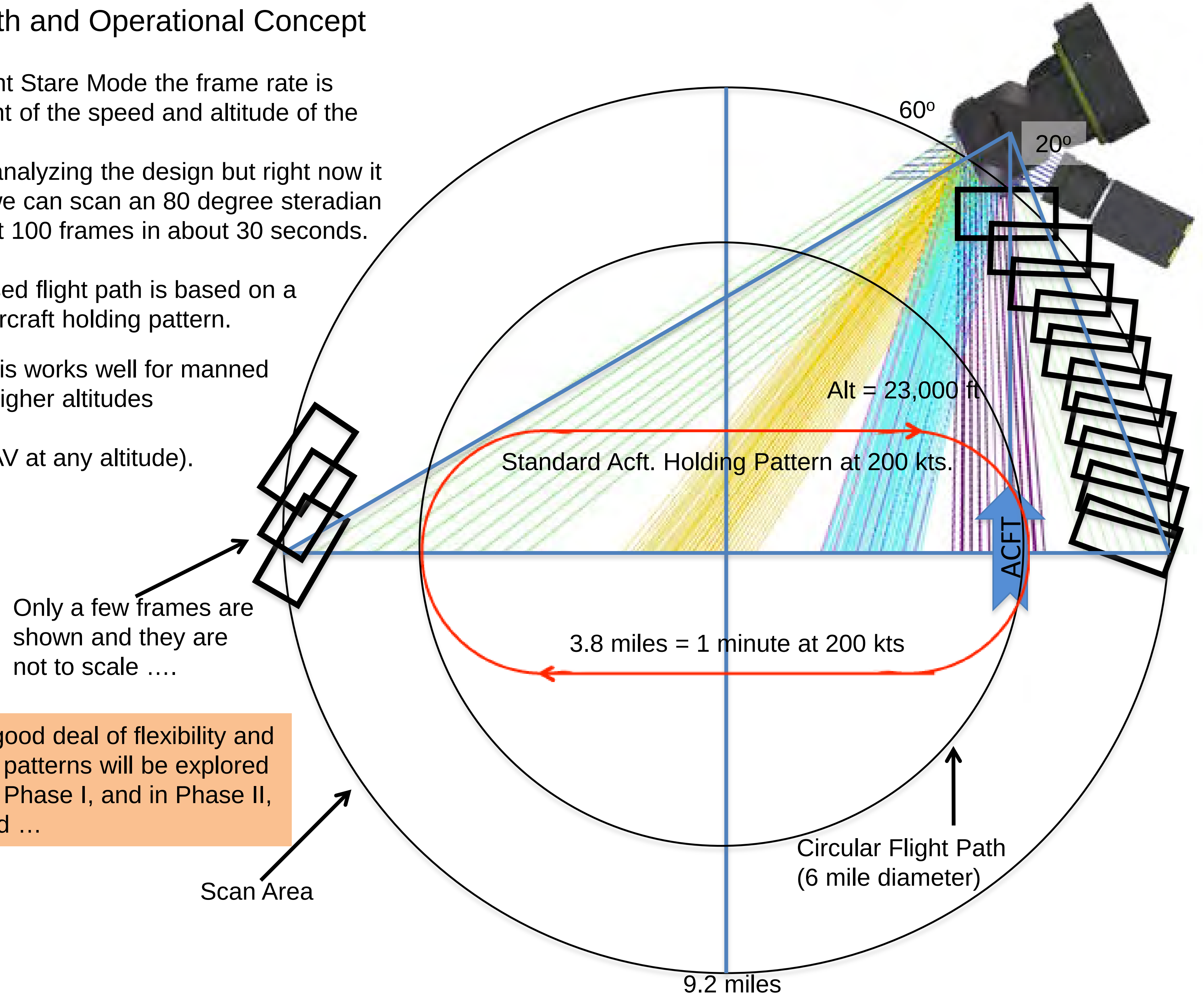
Flight Path and Operational Concept

In Persistent Stare Mode the frame rate is independent of the speed and altitude of the aircraft.
We're still analyzing the design but right now it looks like we can scan an 80 degree steradian using about 100 frames in about 30 seconds.

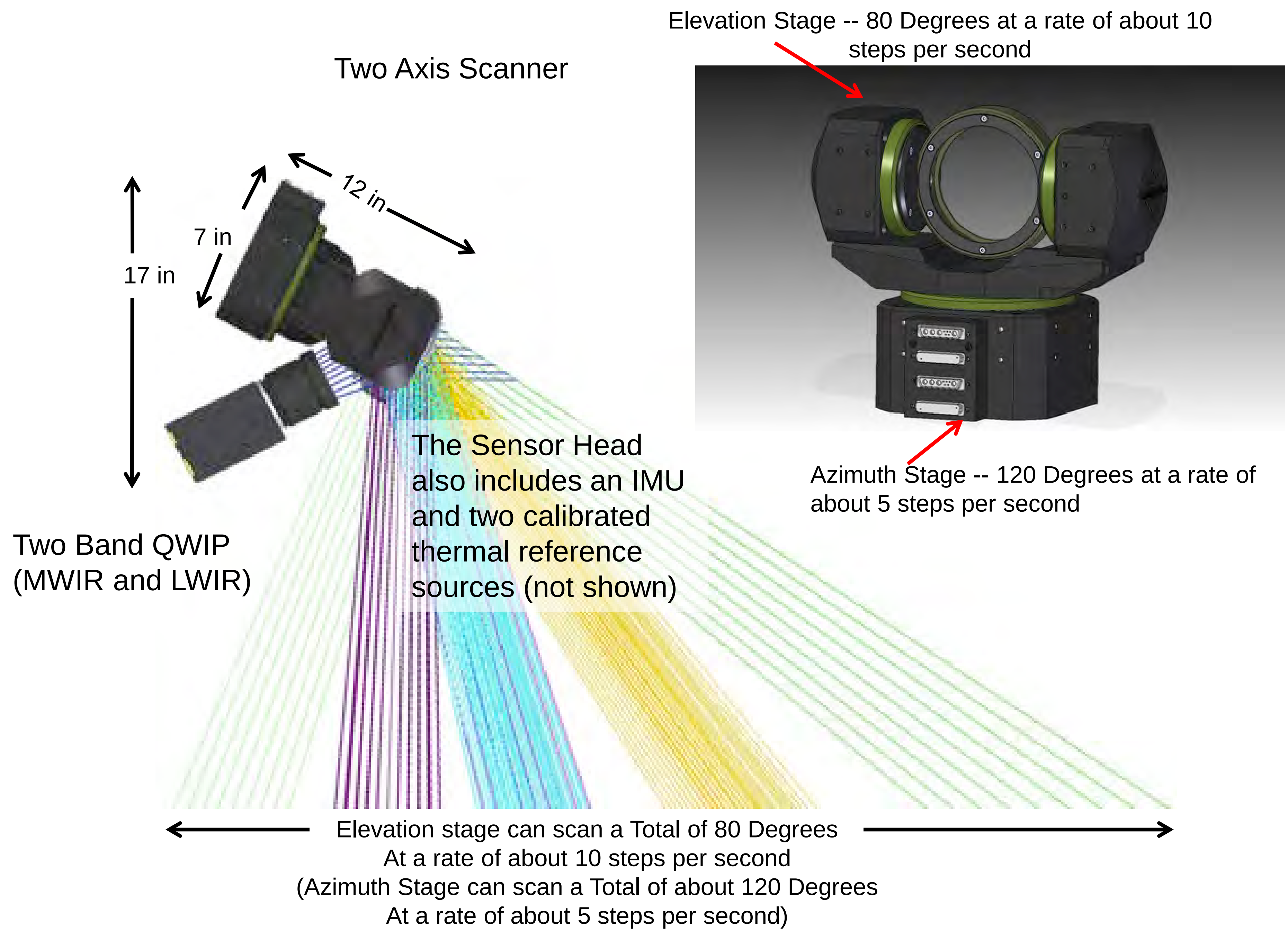
The proposed flight path is based on a standard aircraft holding pattern.

We think this works well for manned aircraft at higher altitudes

(or for a UAV at any altitude).



There's a good deal of flexibility and other flight patterns will be explored later in the Phase I, and in Phase II, and beyond …


Two Axis Scanner
Elevation Stage -- 80 Degrees at a rate of about 10 steps per second
12 in
7 in
17 in
Two Band QWIP (MWIR and LWIR)
The Sensor Head also includes an IMU and two calibrated thermal reference sources (not shown)
Azimuth Stage -- 120 Degrees at a rate of about 5 steps per second
Elevation stage can scan a Total of 80 Degrees
At a rate of about 10 steps per second
(Azimuth Stage can scan a Total of about 120 Degrees
At a rate of about 5 steps per second)

Questions?


#1 Band 1:Line4Mosaic16bitLW.tif
File Overlay Enhance Tools Window
XIOMAS