Airborne Wide Area Imager for Wildfire Mapping and Detection

NASA PHASE II SBIR
BRIEFING FOR
TFRSAC

NOVEMBER 2010

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 Company Profile

- Xiomas is a small business started by two ex-Daedalus Engineers
  - John Green
    - Xiomas Product Engineer and Business Developer
    - Daedalus Product Engineer since 1989
    - Involved in development of
      - MODIS Airborne Simulator
      - Firefly
      - USFS Daedalus
      - INTA AHS
    - Principle Investigator for UAV Fire Mapper SBIR in 2004
  - David Rein
    - Xiomas Computer Engineer
    - Software Engineer for USFS Daedalus
    - Developed Compression Scheme for the UAV Fire Mapper
  - David Linden
    - Xiomas Senior Scientist
  - Brad Cook
    - Xiomas Electrical Engineer

- Our Goal is to Develop Imaging Systems for
  Environmental Remote Sensing and Homeland Security
  - Innovative
  - High Performance
  - Low Cost

How are the programs structured?

•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 $100,000. STTR Phase 1 contracts are typically for one year with a maximum funding of $100,000.

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 $600,000.

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 was at 10,000 feet, the low end of the “operational environment” .

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

During the transition to TRL 9 we expect that we’ll find some problems, weaknesses, deficiencies, etc.
We don’t know what those are right now, but there will almost certainly be something.

Wide Area Imager
Fire Application Requirements

- Detect 10 - inch square, 600°C hot spots
- Generate terrain imagery through smoke from an altitude of 30,000 to 40,000 feet
- Locate the image pixels to a map accuracy of 10 meters
- Image terrestrial features with dimensions of around 2 meters in order to observe natural and man-made fire barriers
- Measure fire temperature to ±10% accuracy
- Measure temperatures up to 1000 degrees C
- Transmit geometrically corrected and classified imagery in near real time to centralized spatial data base
- The system must be capable of autonomous or remote operation
- The system must small (goal is 75 lbs) for light aircraft (Bravo II or King Air) or UAS installations (Ikhana)
- Possibly generate fuel loading and burn area classification maps

Wide Area Imager Summary Description

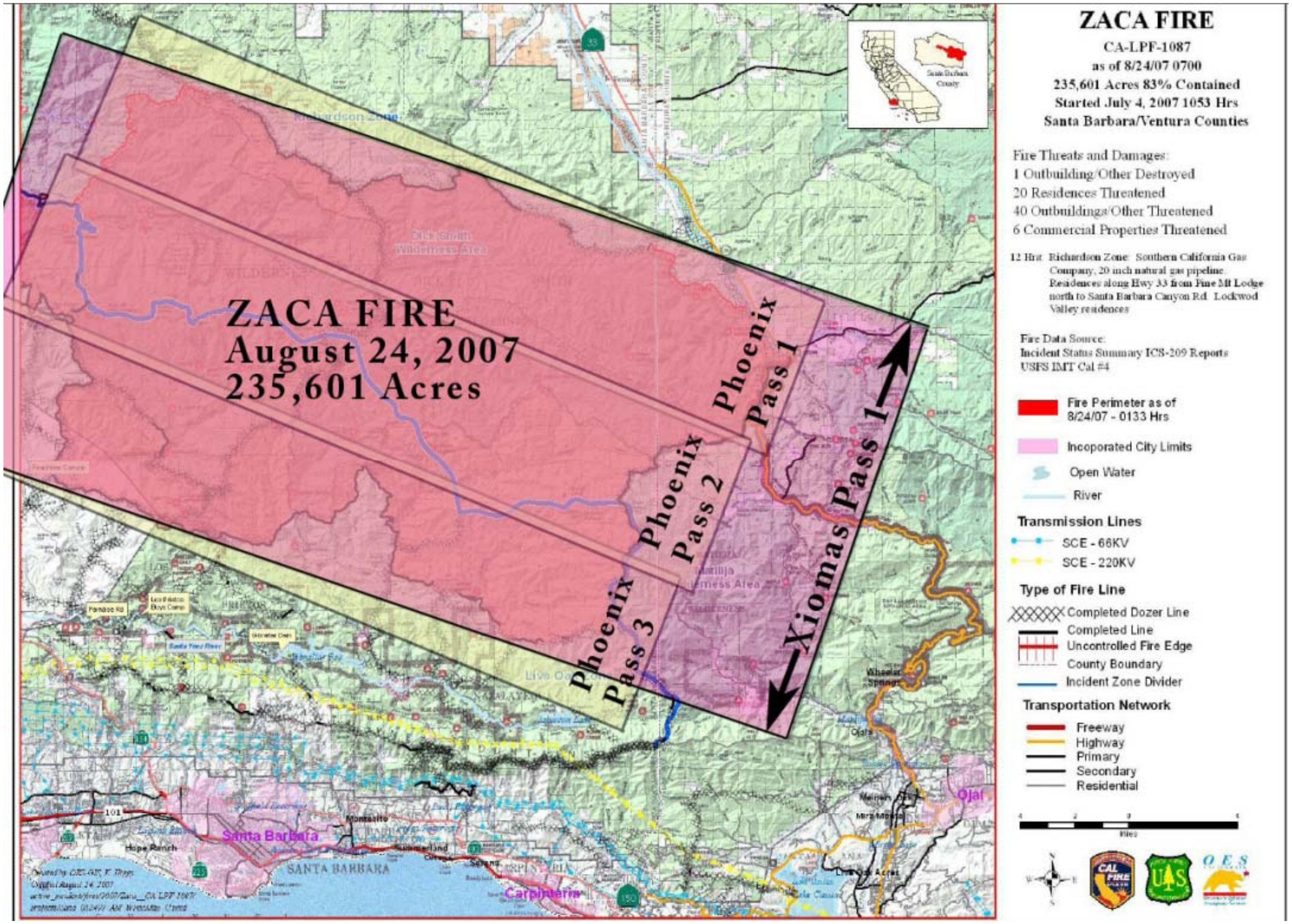
- Step Stare Optical Configuration combines
  High Resolution Cameras with
  Wide Field of View scanning mirror
- High Resolution (nominally 300 uRadians) yields
  12 foot pixel from 40,000 ft.
- 90 Degree Field of View yields 80,000 foot swath width
- Operating at 300 mph (260 knots) yields 2.9 million Acres per Hour
- Up to 6 bands
  - MWIR 4.4 um – 5.4 um
  - LWIR 8 um – 9 um
  - ~~0.52 - 0.6 um (TM Band 2)~~
  - ~~0.63 - 0.69 um (TM Band 3)~~
  - ~~0.76 - 0.90 um (TM Band 4)~~
  - ~~1.6 um (TM Band 5)~~
  - These four bands have been replaced with a single Visible sensor as we shifted funds to the IR Lens and the Mirrors

Primary Sensors for
Fire Detection and Terrain Mapping

Secondary Sensors for
Burn Area Reflectance Classification
and
Normalized Difference Vegetation Index

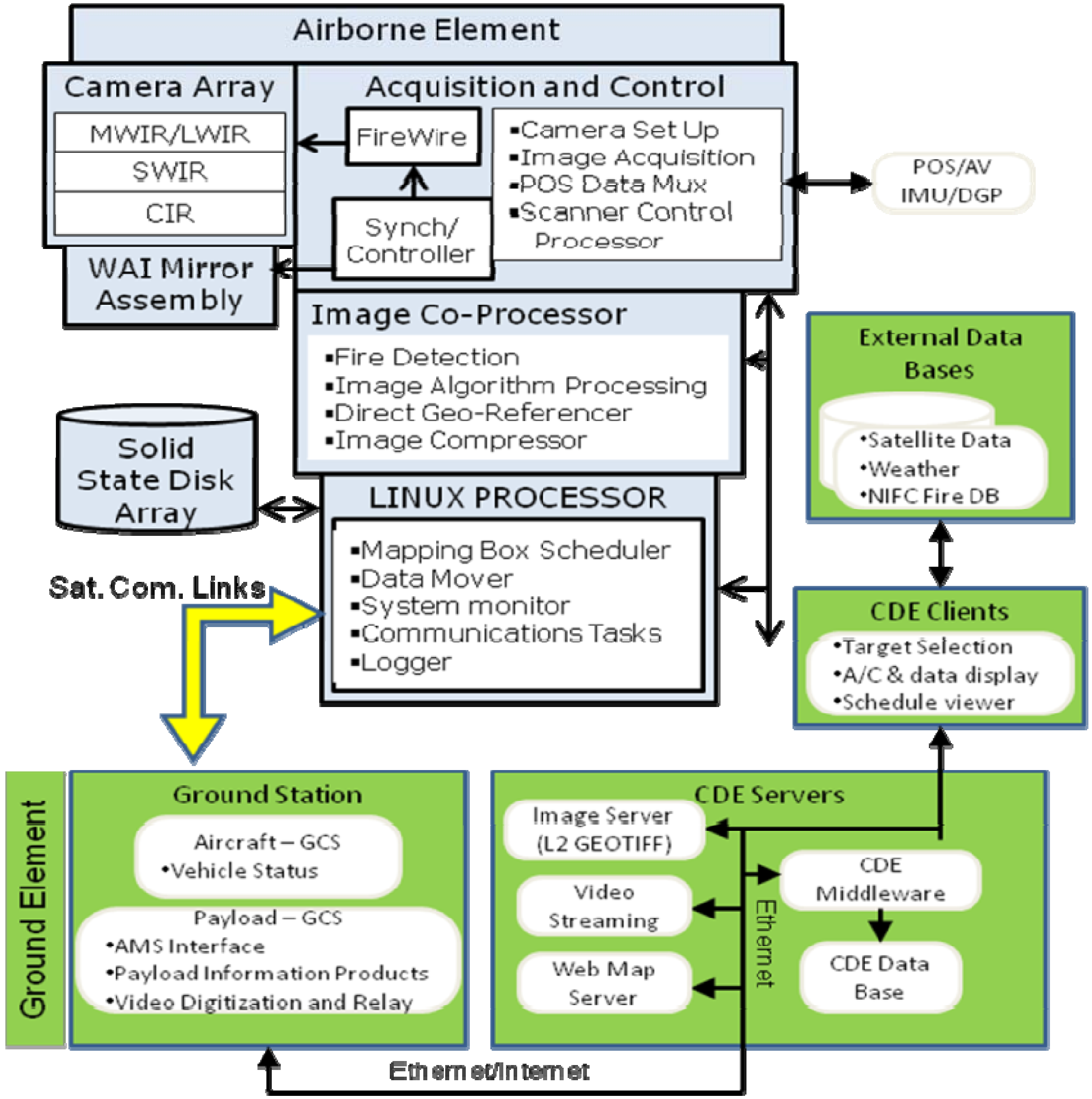
- Real Time Image Classification and Geo-Rectification
- Autonomous/Remote Operation
- Data Transmission via Wireless Data Link to Ground or Satellite

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



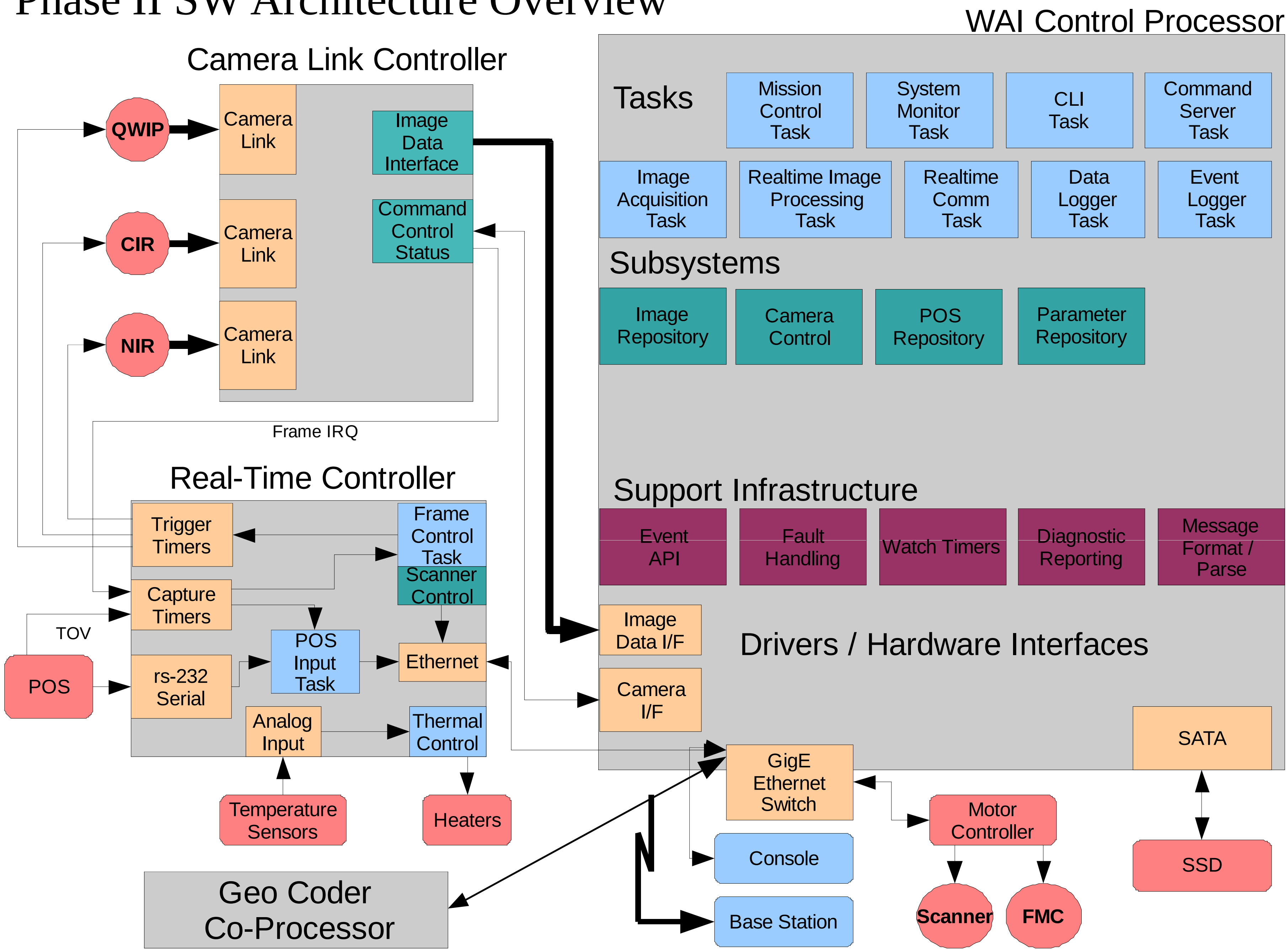
Coverage of the current Phoenix system operated by the U.S. Forest Service National Infrared Operations group. The Phoenix system has a 120 degree field of view and covers a swath approximately 6 miles wide from 10,000 feet. At this altitude the Phoenix system has a 12.5 foot pixel at nadir. The proposed 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.

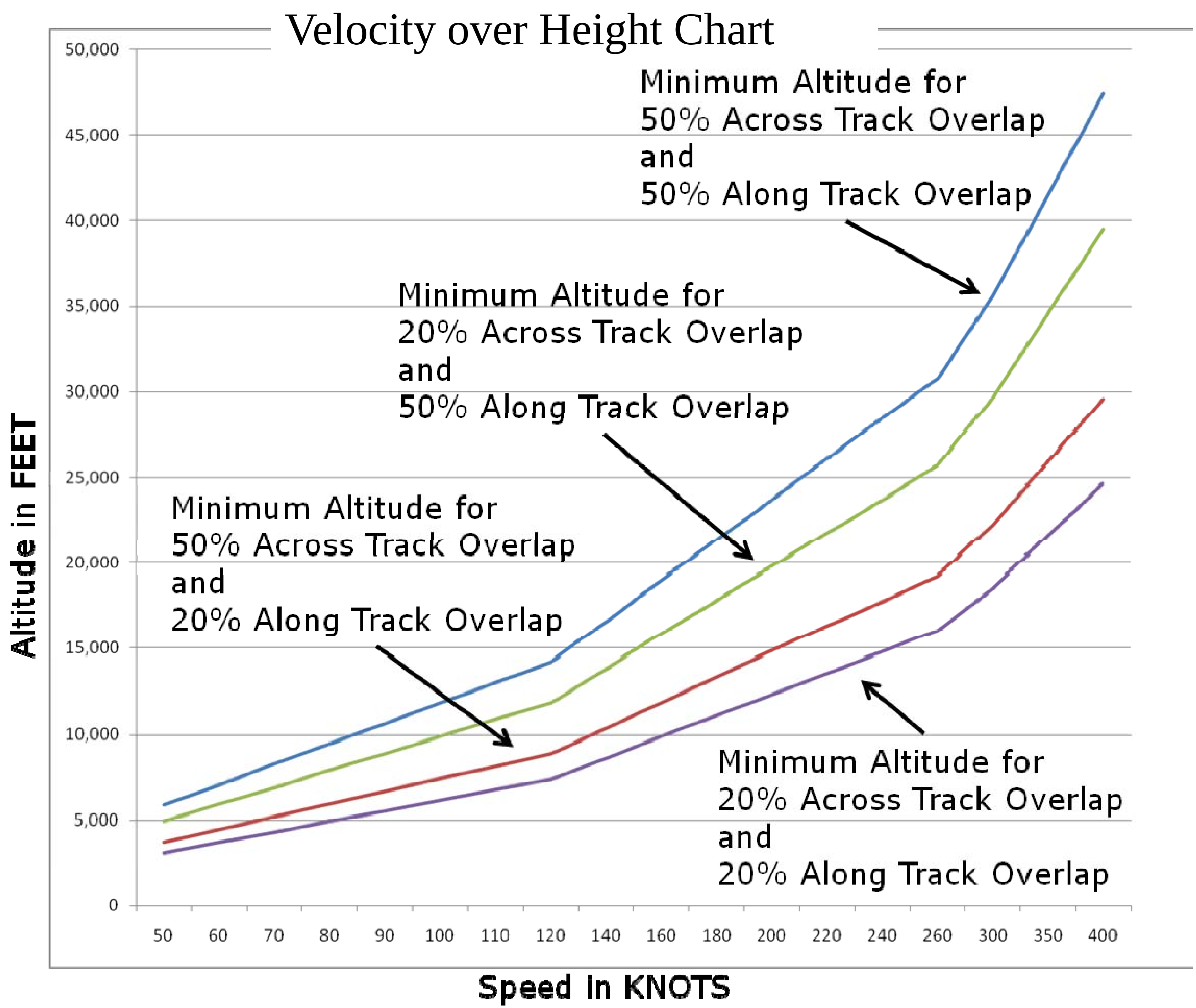
Xiomas Wide Area Imager Shown Integrated with the NASA CDE



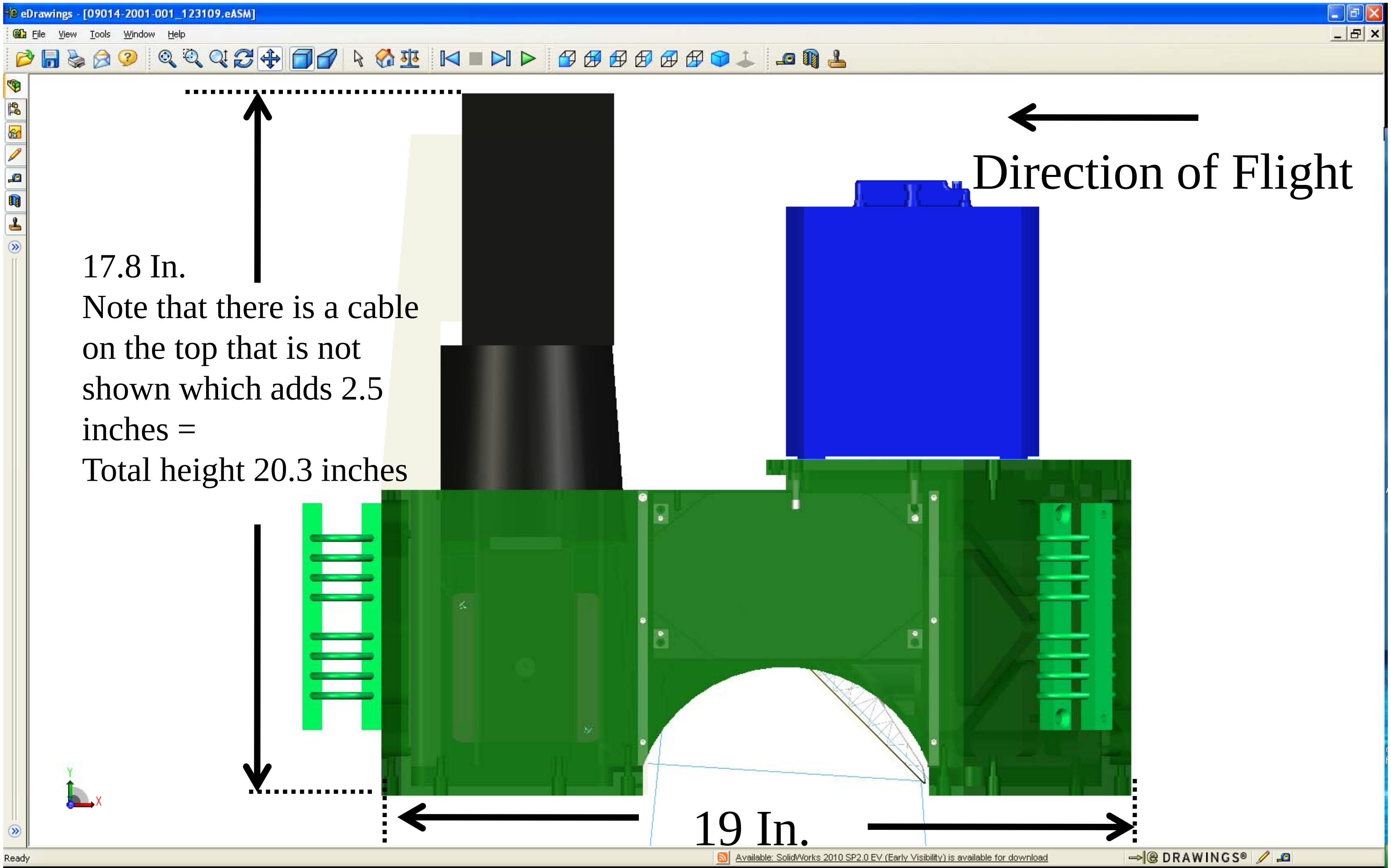
The CDE is NASA technology. Xiomas intends to developed the Wide Area Imager to interface with the CDE.

Phase II SW Architecture Overview





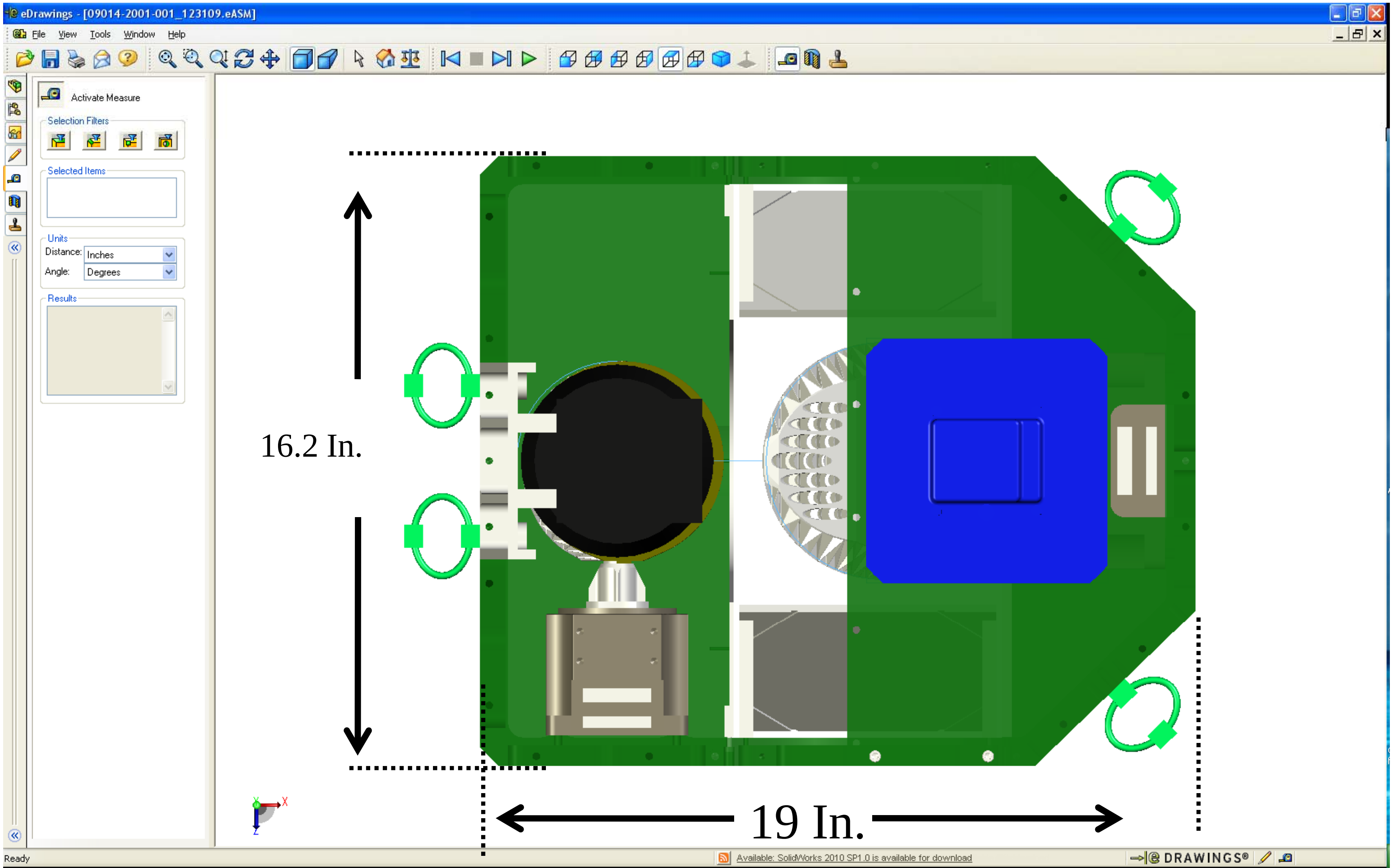
Velocity over Height Chart
Minimum Altitude for
50% Across Track Overlap
and
50% Along Track Overlap
Minimum Altitude for
20% Across Track Overlap
and
50% Along Track Overlap
Minimum Altitude for
50% Across Track Overlap
and
20% Along Track Overlap
Minimum Altitude for
20% Across Track Overlap
and
20% Along Track Overlap
Altitude in FEET
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
50 60 70 80 90 100 110 120 140 160 180 200 220 240 260 300 350 400
Speed in KNOTS



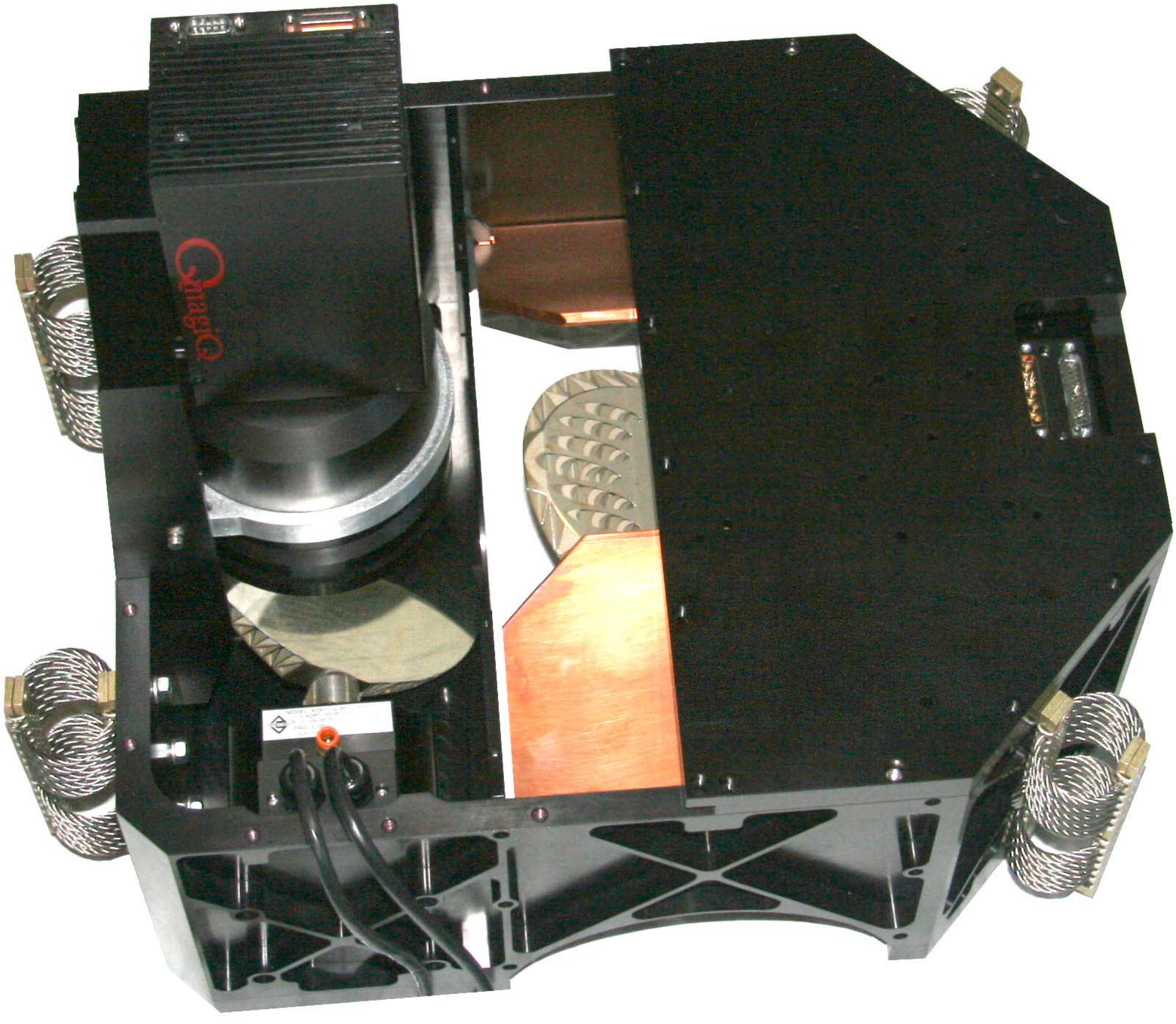
Xiomas Wide Area Imager preliminary Sensor Head Mechanical Outline. Subject to Change

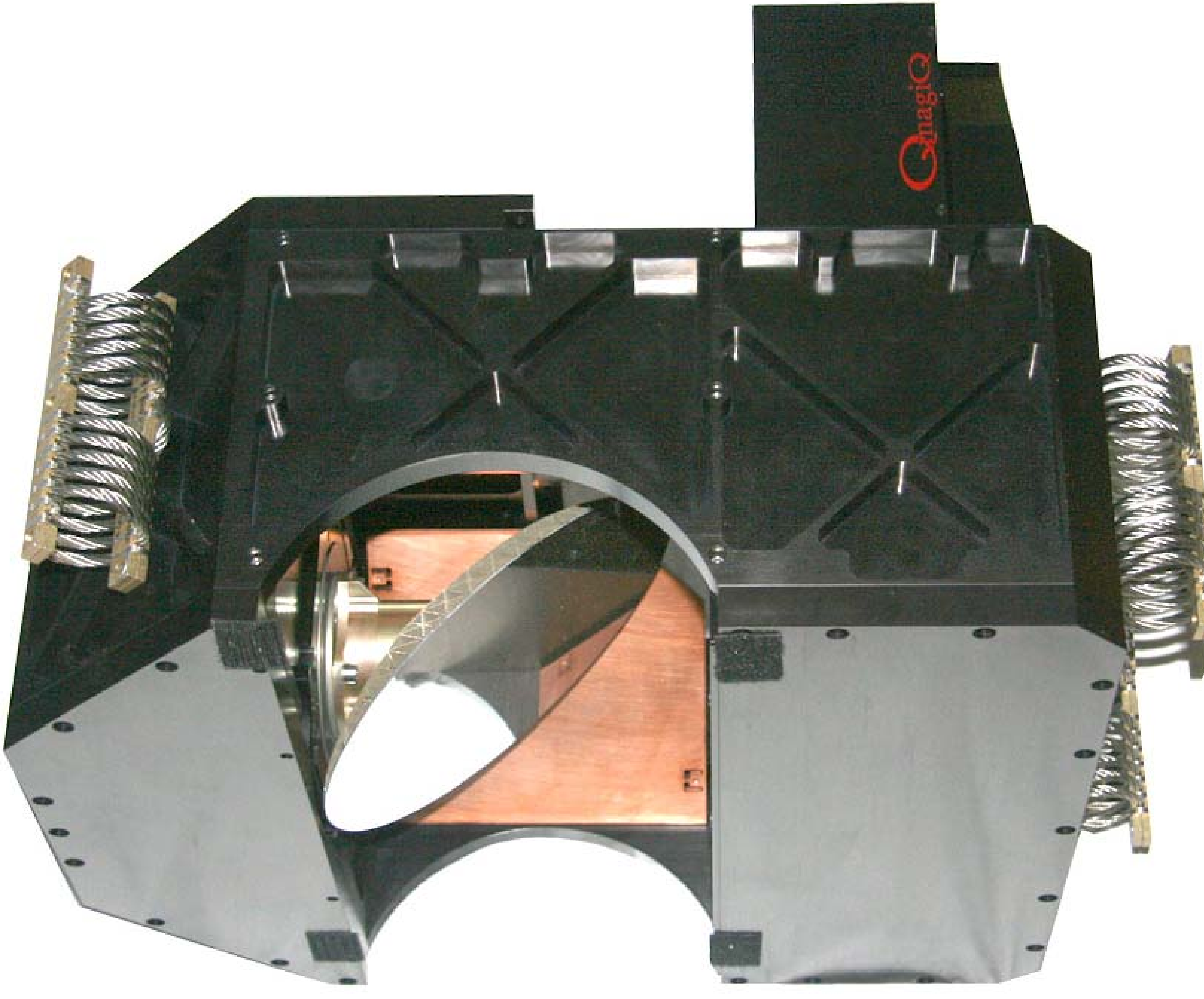
Xiomas Confidential and Proprietary

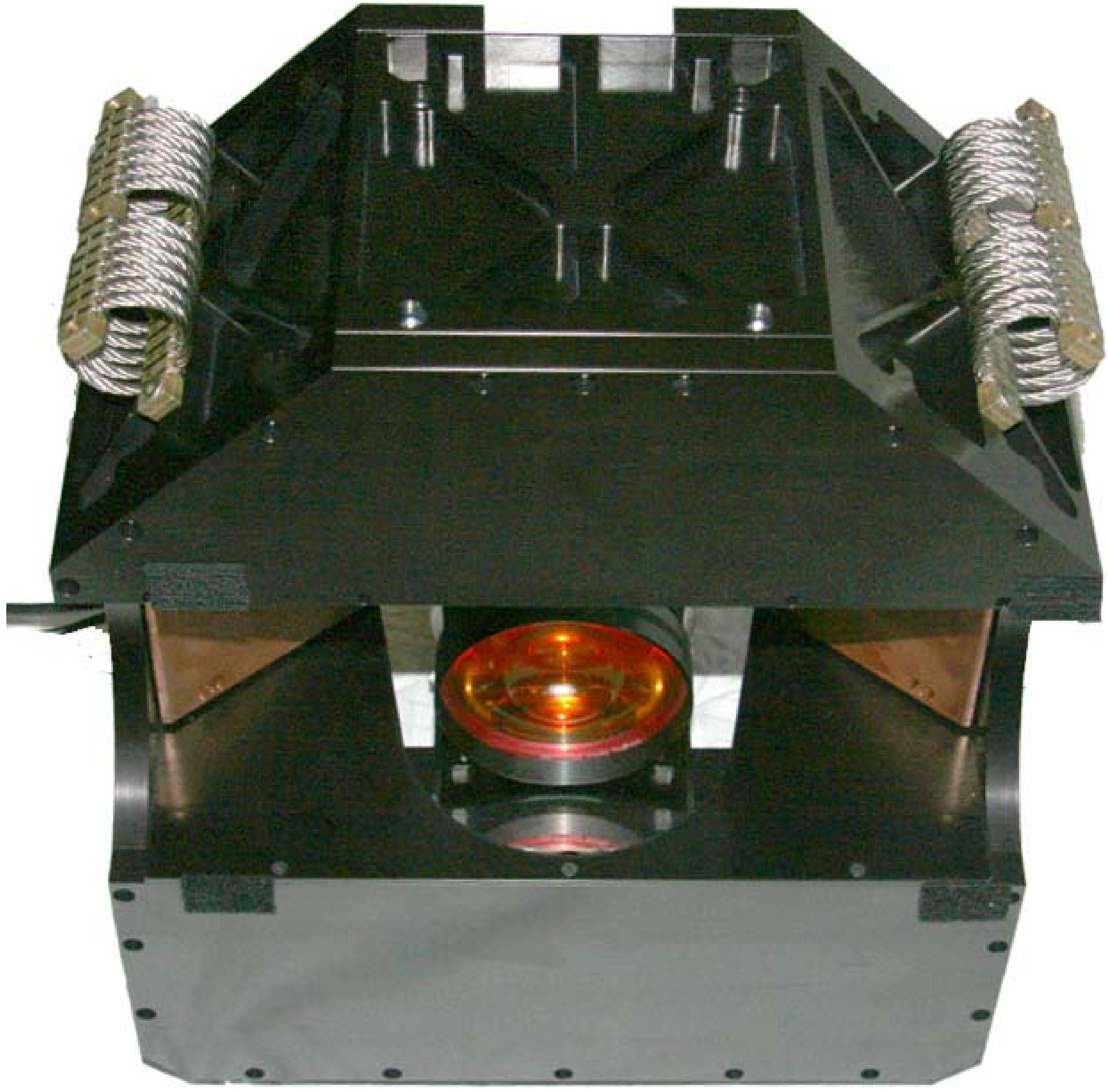
1-7-2010

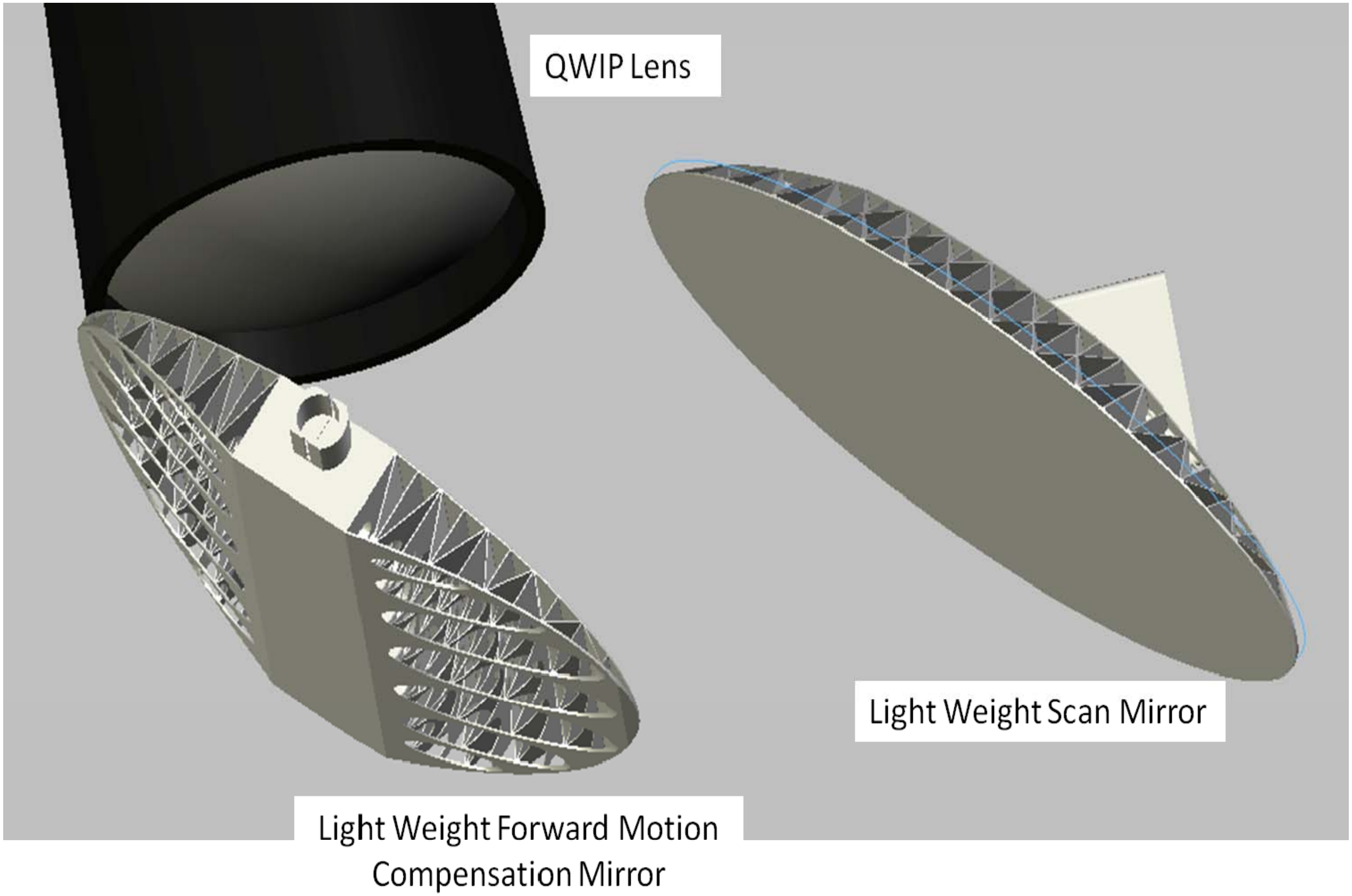


Xiomas Wide Area Imager preliminary Sensor Head Mechanical Outline. Subject to Change
Xiomas Confidential and Proprietary
1-7-2010




QmagiQ

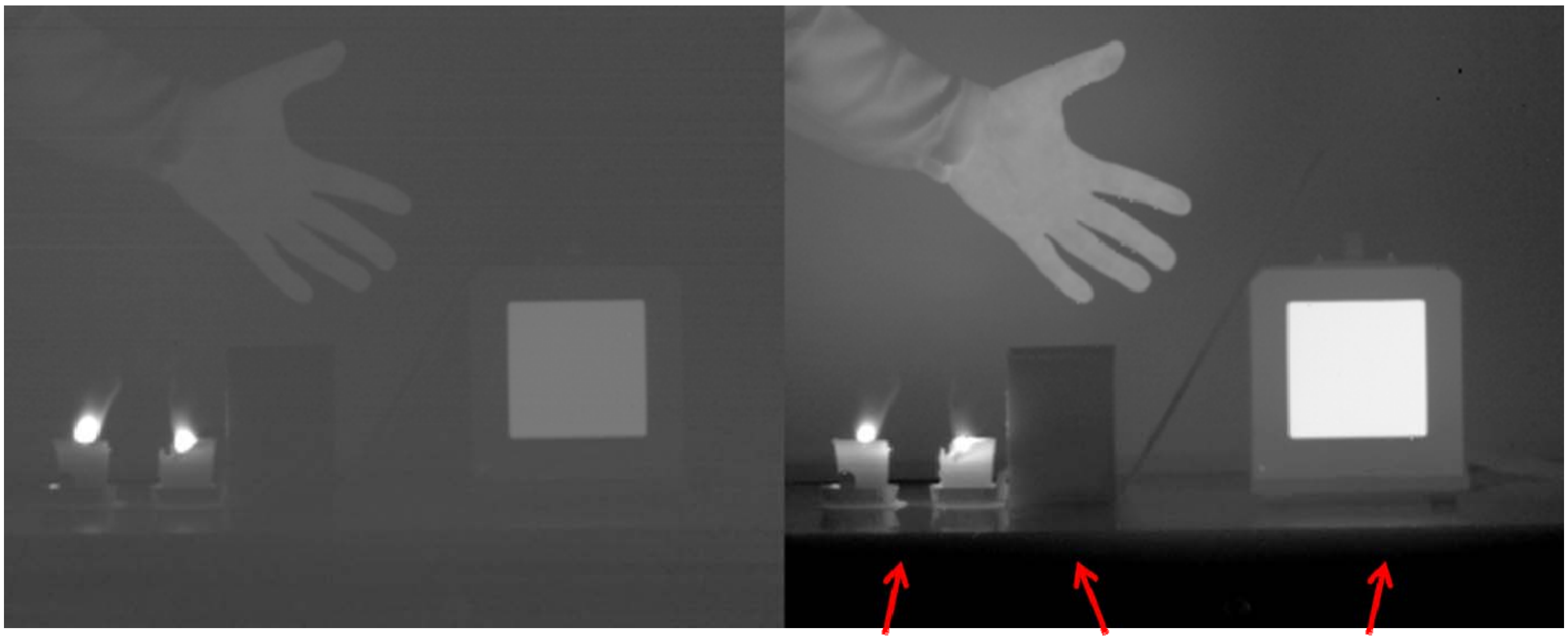



QWIP Lens
Light Weight Scan Mirror
Light Weight Forward Motion Compensation Mirror

Test 3 quick look samples:

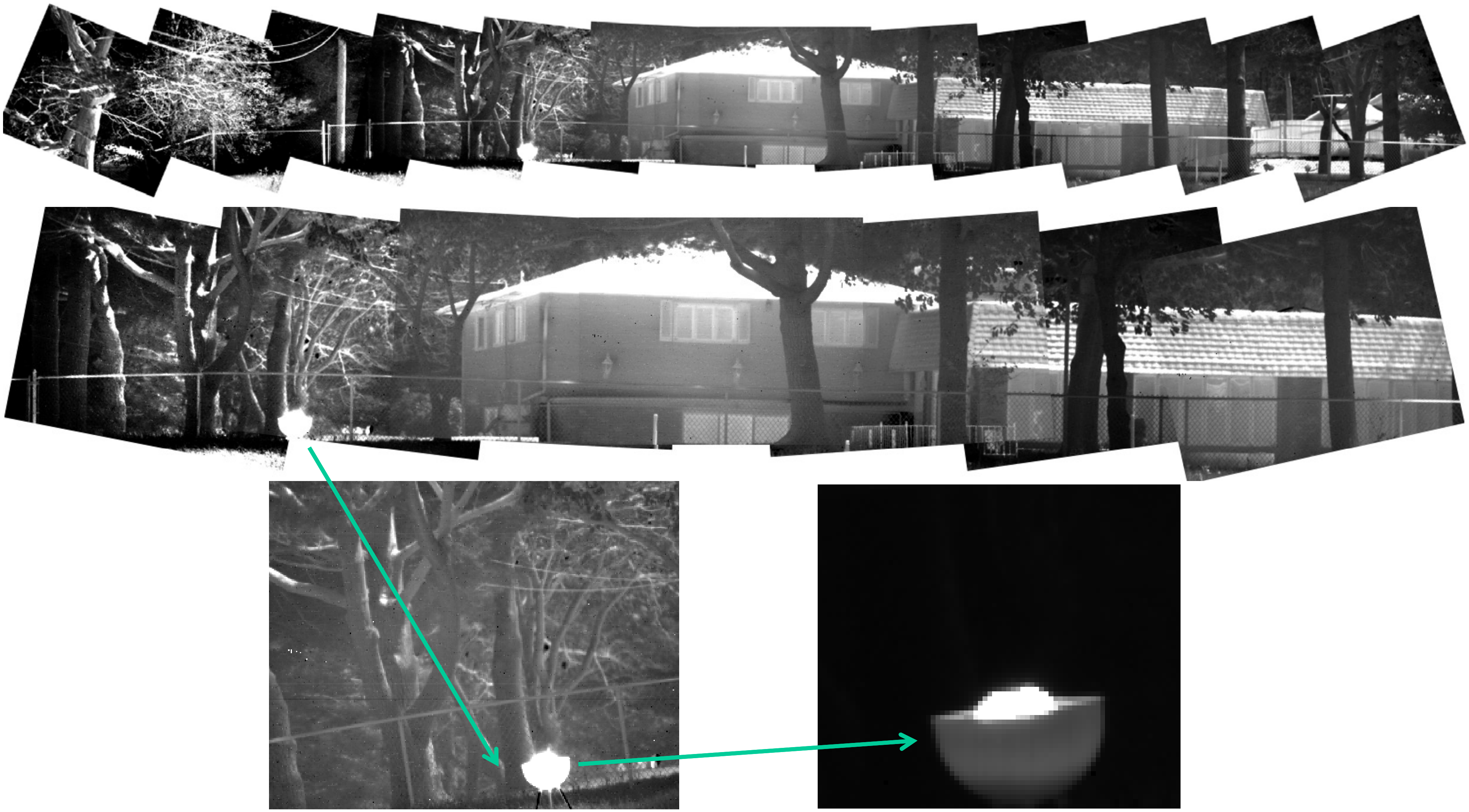
- MWIR at Low Bias and Short Integration (0.275 ms)
- Candles at 1000 K do not saturate

- LWIR at Moderate Bias and Moderate Integration (10 ms)
- Candles at 1000 K do saturate
- full range is approximately 100 K

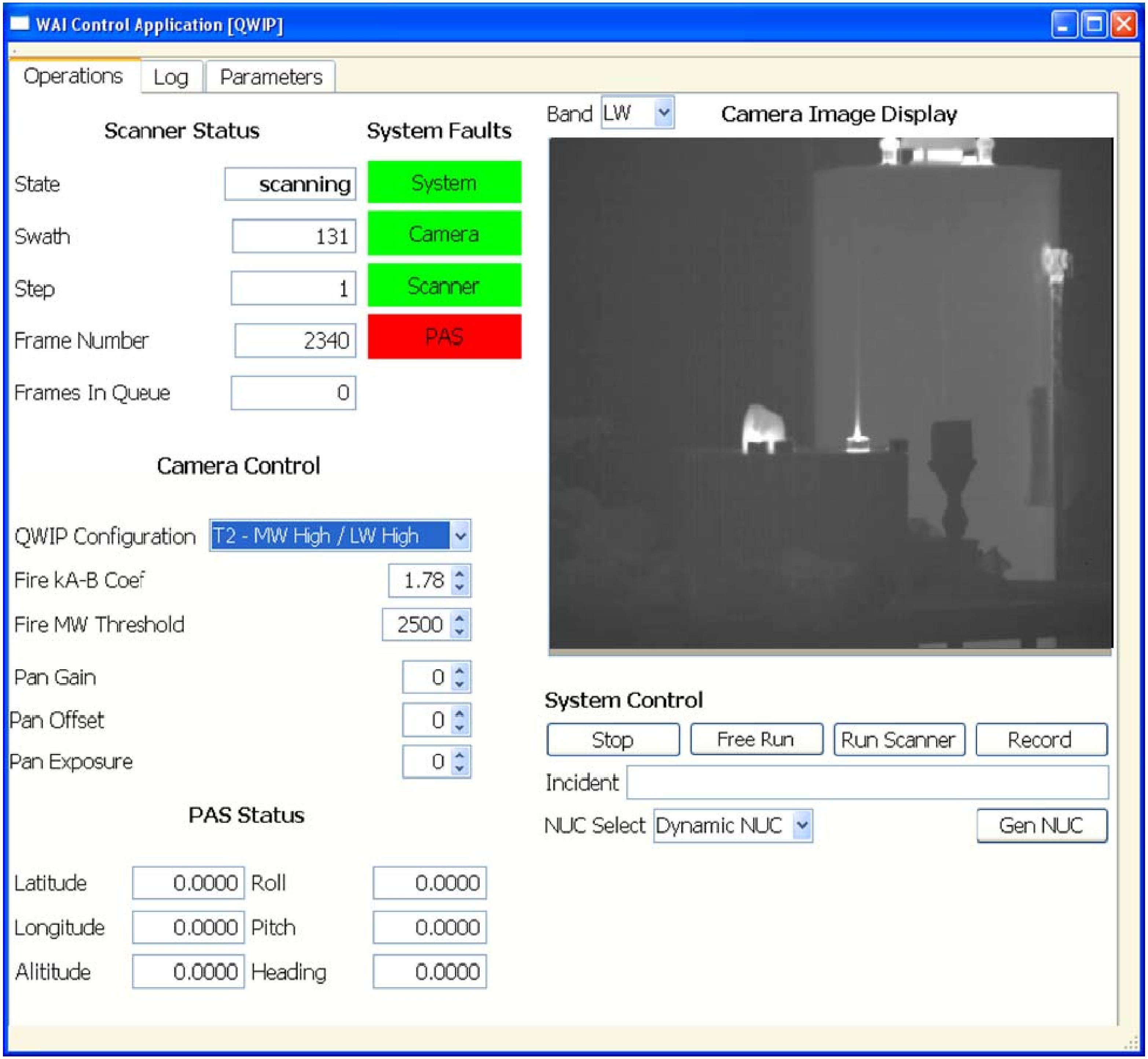


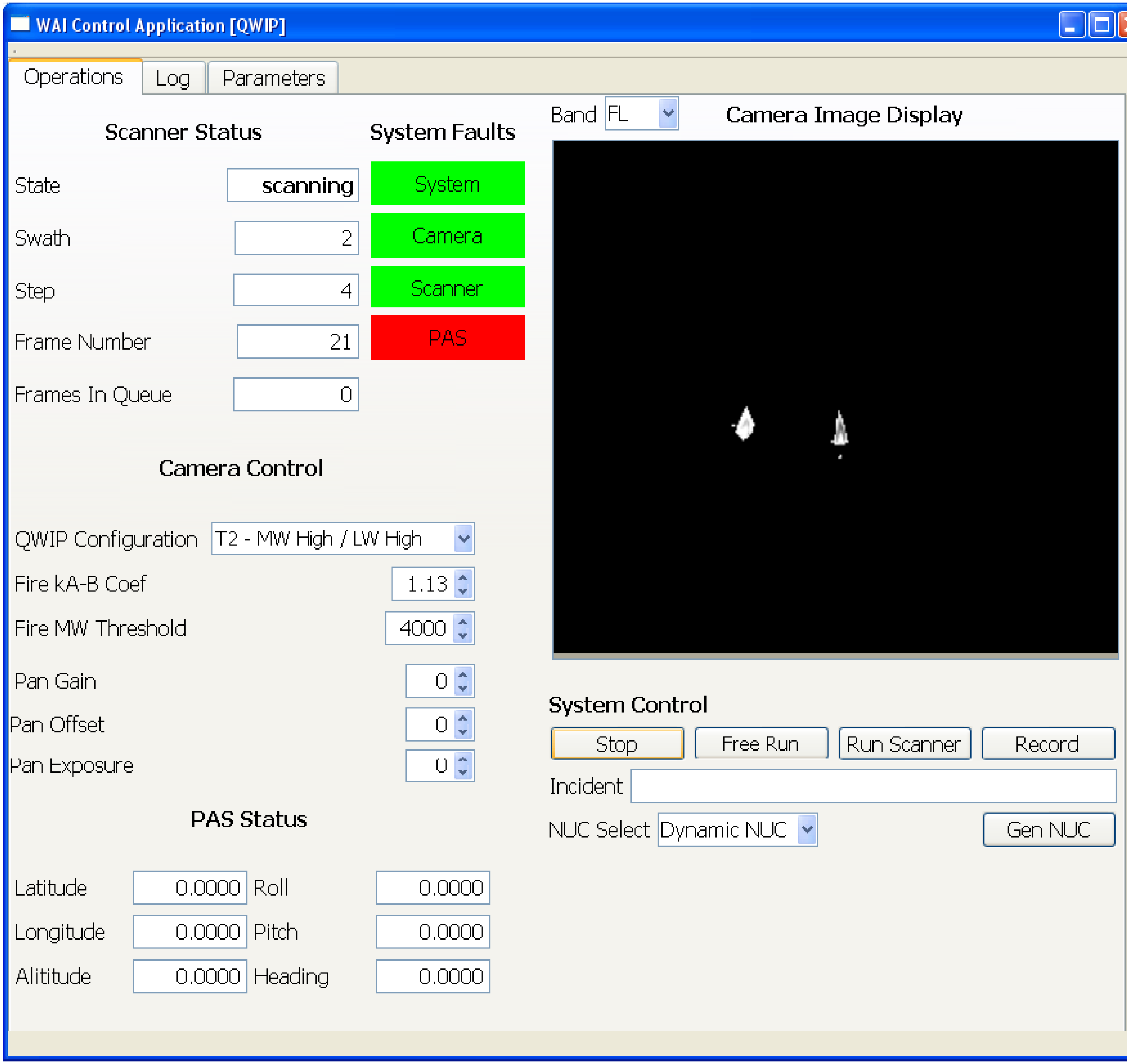
Sample image from test 3. 2 point NUC (non-uniformity-correction) applied in real time by QmagiQ camera.

First imagery from the WAI

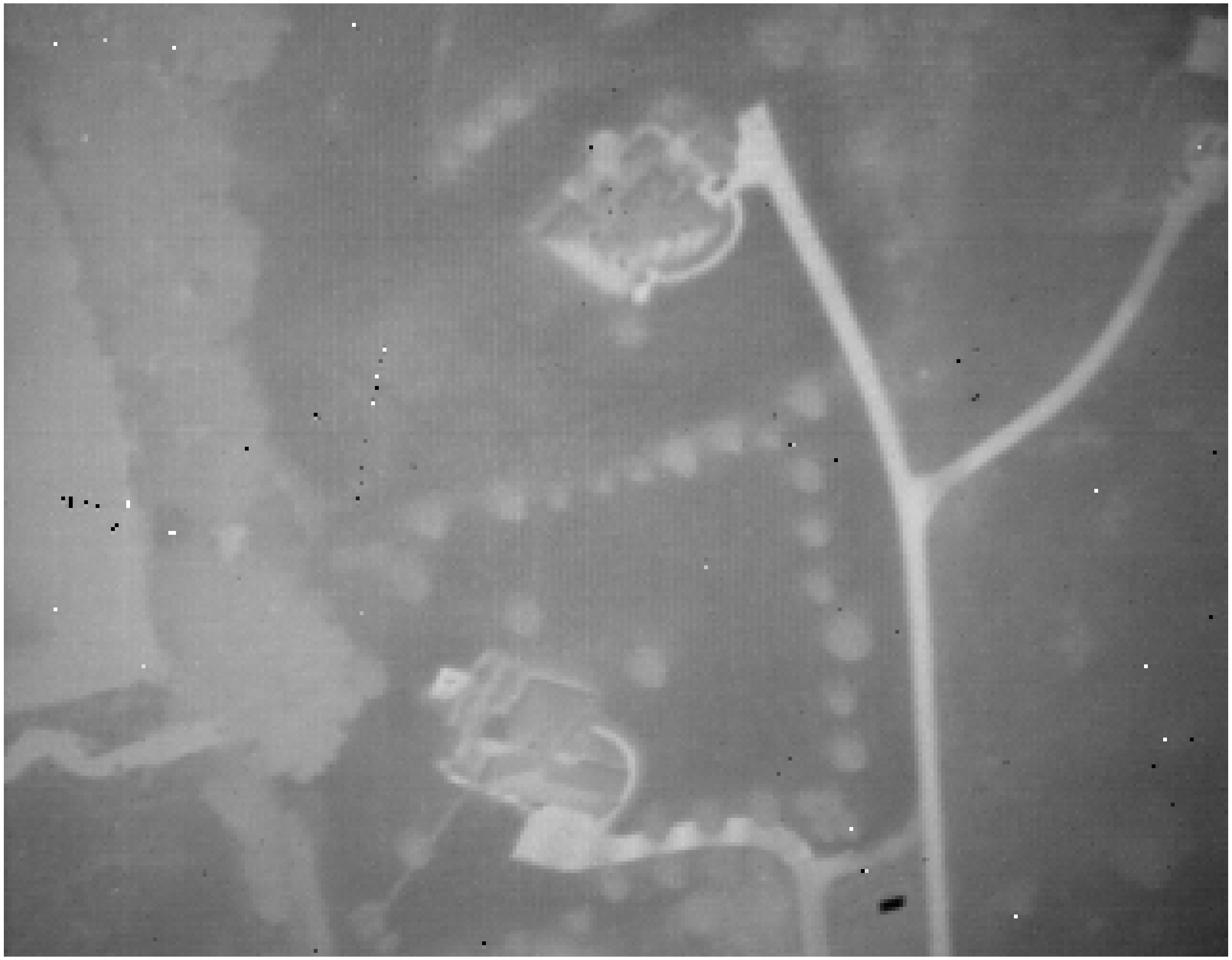


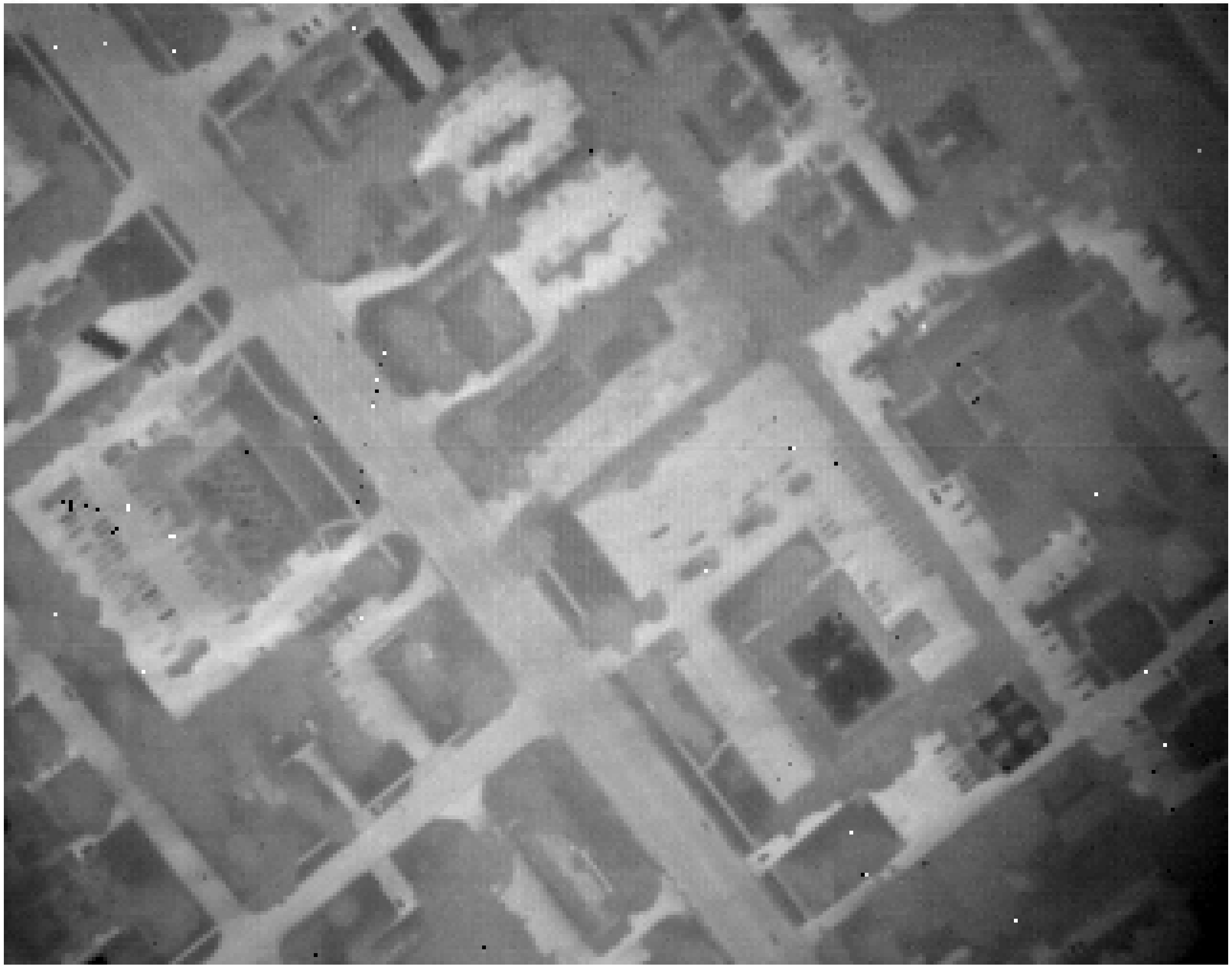
2 Point Non-Uniform Correction Applied, but
Bad Pixel Replacement has not been done

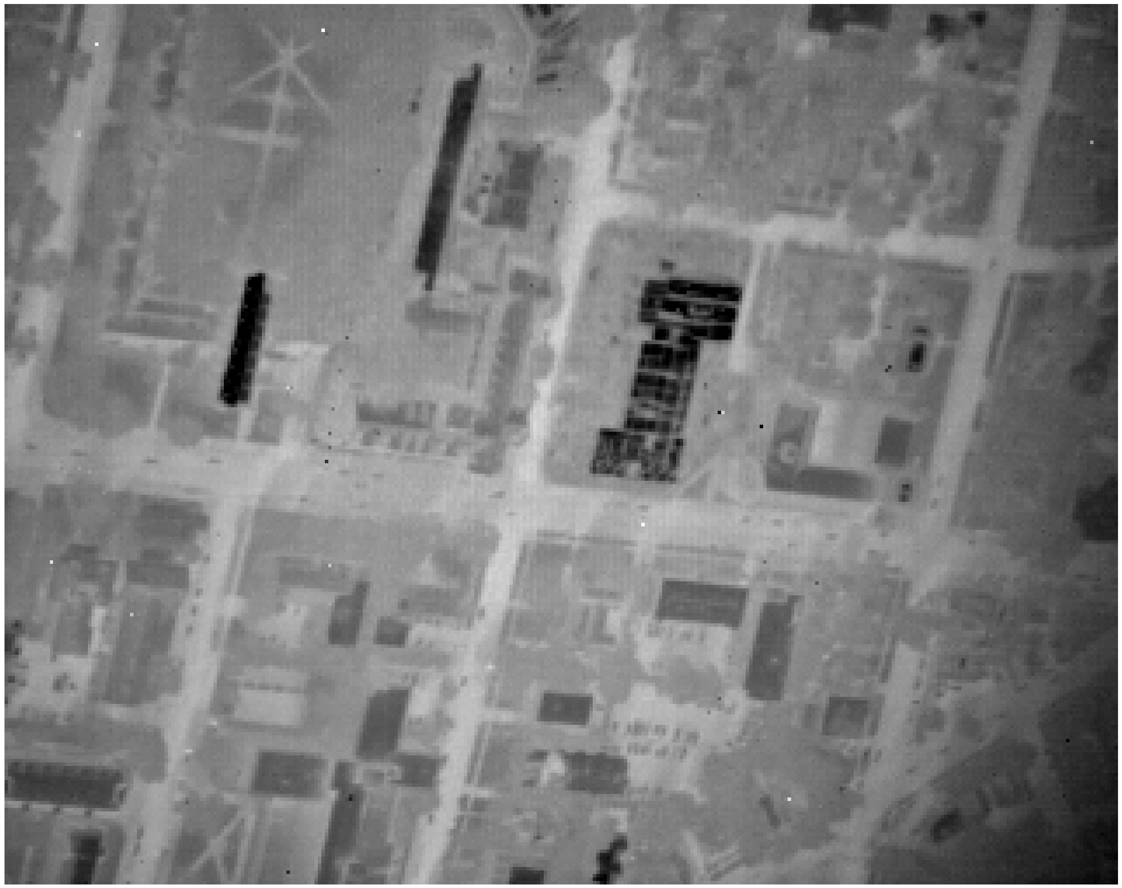

WAI Control Application [QWIP]
Operations
Log
Parameters
Scanner Status
System Faults
State
scanning
System
Swath
131
Camera
Step
1
Scanner
Frame Number
2340
PAS
Frames In Queue
0
Camera Control
QWIP Configuration
T2 - MW High / LW High
Fire kA-B Coef
1.78
Fire MW Threshold
2500
Pan Gain
0
Pan Offset
0
Pan Exposure
0
PAS Status
Latitude
0.0000
Roll
0.0000
Longitude
0.0000
Pitch
0.0000
Alititude
0.0000
Heading
0.0000
Band
LW
Camera Image Display
System Control
Stop
Free Run
Run Scanner
Record
Incident
NUC Select
Dynamic NUC
Gen NUC



WAI Control Application [QWIP]
Operations
Log
Parameters
Scanner Status
System Faults
State
scanning
System
Swath
2
Camera
Step
4
Scanner
Frame Number
21
PAS
Frames In Queue
0
Band
FL
Camera Image Display
Camera Control
QWIP Configuration
T2 - MW High / LW High
Fire kA-B Coef
1.13
Fire MW Threshold
4000
Pan Gain
0
Pan Offset
0
Pan Exposure
0
System Control
Stop
Free Run
Run Scanner
Record
Incident
NUC Select
Dynamic NUC
Gen NUC
PAS Status
Latitude
0.0000
Roll
0.0000
Longitude
0.0000
Pitch
0.0000
Alititude
0.0000
Heading
0.0000





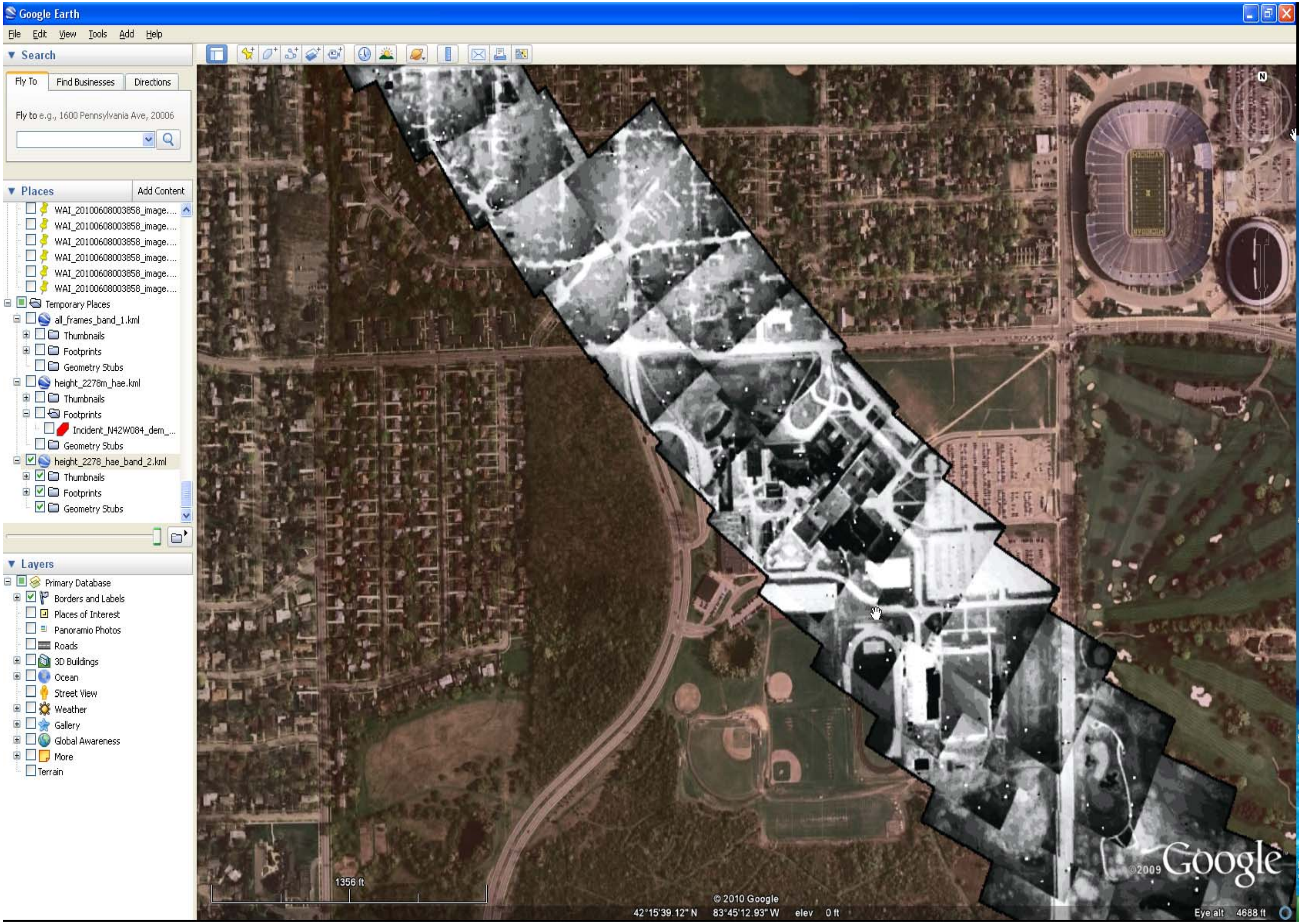



Three Fires

We took the pixel map for the MWIR image of the three fires in the flight test imagery and re-sampled them to simulate the larger pixels we would see from an altitude of 10 km (32500 feet).

Red cells are fire and the clear cells are the background consisting of a variety of objects including sidewalk, road, rocks, and grass (see the image above):
Note that we took care in the re-sampling to make sure that the three fires do not overlap.
From the analysis we believe that the system is capable of detecting all three of the test fires from 32,500 feet. The two small fires are 39 square inches (6.25 by 6.25); the larger fire in the middle is 132 square inches (11.5 by 11.5 inches).

Below is the average of 25 pixels representing a simple re-sampling of the data from the flight test altitude of 6500 feet to the proposed operational altitude of 32500 feet		
3366.16	2326.28	2251.64
2384.12	4364.12	2351.16
2415.64	2404.52	3110.96
2410.85	2418.45	2385.2
Below is the same re-sampled data including 18% attenuation due to atmosphere		
2760.251	1907.55	1846.345
1954.978	3578.578	1927.951
1980.825	1971.706	2550.987
1976.897	1983.129	1955.864


Google Earth
File Edit View Tools Add Help
Search
Fly To
Find Businesses
Directions
Fly to e.g., 1600 Pennsylvania Ave, 20006
Places
Add Content
WAI_20100608003858_image....
WAI_20100608003858_image....
WAI_20100608003858_image....
WAI_20100608003858_image....
WAI_20100608003858_image....
WAI_20100608003858_image....
Temporary Places
all_frames_band_1.kml
Thumbnails
Footprints
Geometry Stubs
height_2278m_hae.kml
Thumbnails
Footprints
Incident_N42W084_dem_...
Geometry Stubs
height_2278_hae_band_2.kml
Thumbnails
Footprints
Geometry Stubs
Layers
Primary Database
Borders and Labels
Places of Interest
Panoramio Photos
Roads
3D Buildings
Ocean
Street View
Weather
Gallery
Global Awareness
More
Terrain
1356 ft
© 2010 Google
42°15'39.12" N 83°45'12.93" W elev 0 ft
©2009 Google
Eye alt 4688 ft

Direct Geo-Referencing Accuracy

	POS AV 510	AeroTech ADRT-100-85 Across Track Mirror	Camera Mechanical Alignment Error (motion due to thermal and vibration)	Total RMS Error in mRad	Total RMS Error in Meters assuming an altitude of 12km
Position (m)	0.5 – 2.0				
Roll (mrad)	0.14	0.024	0.5	0.52	6.24
Pitch (mrad)	0.14	0.048	0.5	0.52	6.26

Table 4 – Geometric Tolerances with POS AV 510

Using the high accuracy POS AV 510 and assuming an altitude of 12km we calculate the RMS error in the roll and pitch direction as shown above. These errors should add in quadrature resulting in a total of 8.9 meters, the position error can then be added to this, resulting in a total of 9.4 to 10.9 meters.

	POS AV 310	AeroTech ADRT-100-85 Across Track Mirror	Camera Mechanical Alignment Error (motion due to thermal and vibration)	Total RMS Error in mRad	Total RMS Error in Meters assuming an altitude of 12km
Position (m)	0.5 – 2.0				
Roll (mrad)	0.52	0.024	0.5	0.72	8.66
Pitch (mrad)	0.52	0.048	0.5	0.72	8.68

Using the moderate accuracy POS AV 310 and assuming an altitude of 12km we calculate the RMS error in the roll and pitch direction as shown above. These errors should add in quadrature resulting in a total of 12.3 meters, the position error can then be added to this, resulting in a total of 12.8 to 14.3 meters.

Wide-Area Imager
Orthorectification Processing Unit (OPU)

•Xiomas and ITT VIS (the ENVI people) developed the Wide-Area Imager (WAI) Orthorectification Processing Unit (OPU)

•The OPU is an automated, direct-georeferencing orthorectification system which processes data collected by the Wide Area Imager in near-real time.

•The core algorithms are adapted from the ENVI Rigorous Orthorectification Module and modified to orthorectify, mosaic, and compress WAI imagery.

•The WAI OPU is implemented in CUDA, a massively parallel computing architecture developed by NVIDIA, for execution on a Graphics Processing Unit (GPU).

•Hardware Summary:

CPU: 3GHz+ Dual Core CPU
GPU: NVIDIA GTX 285
RAM: 8 GB RAM
OS: 64-bit Fedora Core 10

From the ITT VIS
ENVI Orthorectification Module Whitepaper

Rigorous Orthorectification
•Rigorous orthorectification is the most accurate method of image geolocation and geometric correction.
•Using the rigorous method, high accuracy image geolocation is accomplished by using photogrammetric methods that employ physical sensor models and advanced statistical treatment of elevation and geometric reference data.

The many advantages of the rigorous photogrammetric approach include:
• Highest possible geometrical accuracy for given input data
• Lower operational costs - method is highly stable and requires less external data such as ground control points
• Support of true image orthorectification with sub-pixel geolocation accuracy
• Full photogrammetric functionality readily available for any satellite or airborne sensor, with modest efforts required to develop a sensor model

NASA SBIR/STTR Technologies

Airborne Wide Area Imager for Wildfire Mapping and Detection

Contract No. NNX09CA09C

PI: John M Green
Xiomas Technologies

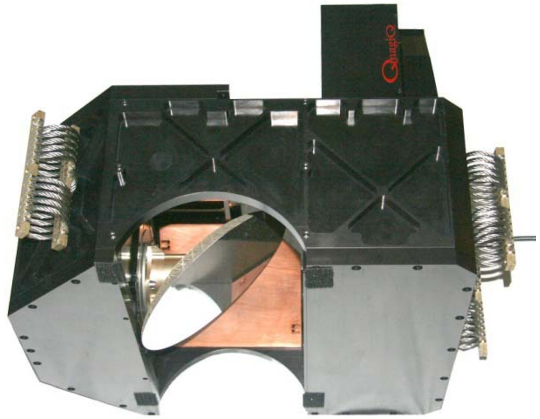
Identification and Significance of Innovation

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

NON-PROPRIETARY DATA