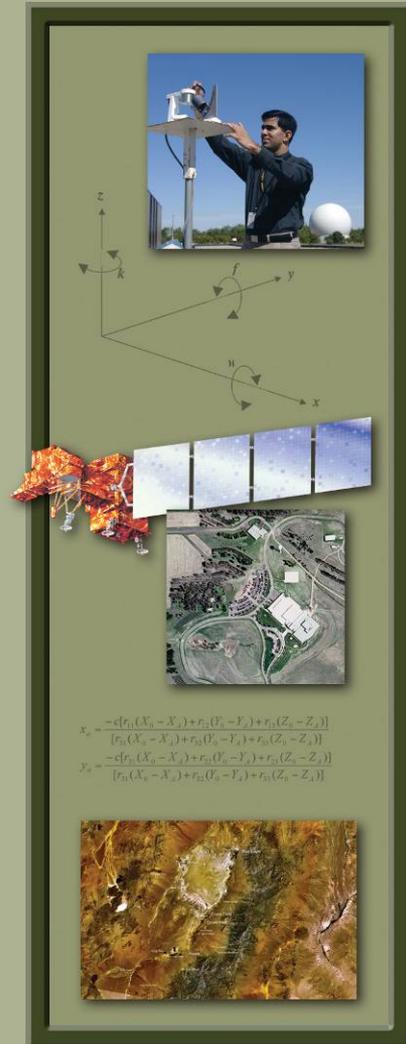


# Digital Aerial Technologies

**Jon Christopherson**  
**SGT, Inc., at USGS EROS**

Work performed under contract: 08HQCN0005



$$x_p = \frac{-d[r_1(X_0 - X_1) + r_2(Y_0 - Y_1) + r_3(Z_0 - Z_1)]}{[r_1(X_0 - X_1) + r_2(Y_0 - Y_1) + r_3(Z_0 - Z_1)]}$$

$$y_p = \frac{-d[r_1(X_0 - X_1) + r_2(Y_0 - Y_1) + r_3(Z_0 - Z_1)]}{[r_1(X_0 - X_1) + r_2(Y_0 - Y_1) + r_3(Z_0 - Z_1)]}$$

# Outline

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- **10:45 – 11:15am Medium Format Cameras, USGS - Jon Christopherson**
  - ◆ - Information on usage for HR/1 Meter Orthoimagery
  - ◆ - Certification by IADIWG - USGS
  - ◆ - LiDAR Acquisition (Same acquisition period as Imagery)
  - ◆ - New Technology?
  - ◆ - Availability in US (Number of Sensors?)
  - ◆ - Applanix 4 Band Sensor – 3 Band Acquisition

# “Large” vs. “Medium” Format

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- In Film Days “Large” meant 9” film, “Medium” meant 2 1/8 ” film
- “Medium” format now approaching film resolution
- 9” film scanned at 25 μm is 9,144 pixels wide
- Latest chips are 8984 pixels wide – 98% of film!!
- What is “Medium” or “Large” format?
  - ◆ Today’s “Medium” is larger than yesterday’s “Large”
- “Large” is typically comprised of multiple smaller (“medium”) cameras
- Is Leica ADS40/80 the only “Large” format camera?
  - ◆ Though other systems are “larger”

$$LF = \sum_{i=1}^n MF_i$$

Manufacturers of LF cameras: please do not take the “equation” wrong!

# Largest Commercially Available

- Phase One P 65+ digital back
- 8984 x 6732 chip!
  - ◆ 53.9 x 40.4 mm
- Film camera b/h ratio with 36mm lens
- 6" GSD at 3,000' AGL
- 1m GSD at 20,000' AGL
- Swath width still narrower than film
- 180 MB image at 8-bit
  - ◆ Each second!



# More Very Large CCDs

- **Kodak 50 MP CCD**

- ◆ Already in use by Hasselblad
- ◆ MFDC with these are ~\$30K
- ◆ All have huge assortment of lenses and other peripherals
- ◆ But NOT the supporting equipment & s/w for aerial applications



- **Spectral Instruments 100 MP sensor**

- ◆ 10,580 × 10,560 pixel CCD
- ◆ Pan only so far
- ◆ Expensive – for now
- ◆ Archiving possibilities?



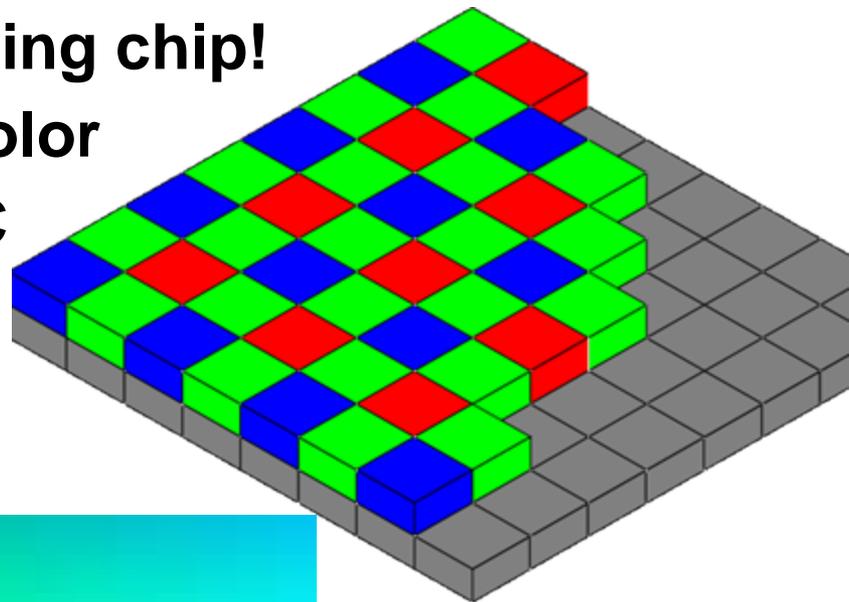
# Can Medium Format Do the Job?

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- Kodak 39 megapixel array has 6.8 micron detectors
- Applanix has 40mm & 60mm lenses
- 40mm lens gives 1m GSD at ~10,000 ft AGL
- 60mm lens gives 1m GSD at ~15,000 ft. AGL
- Image footprint = 7.2km × 5.4km
  
- So can they do some DOQ/NAIP-type work? *Yes.*
- But are they the best choice? The most economical?
  
- Cheaper, lighter, faster
- Less base/height ratio, smaller footprint, other issues

# Bayer Pattern

- Most common form of imaging chip!
- Well-developed, pleasing color
- Can NOT do electronic FMC
- Slight drop in resolution
- Minor spectral effects



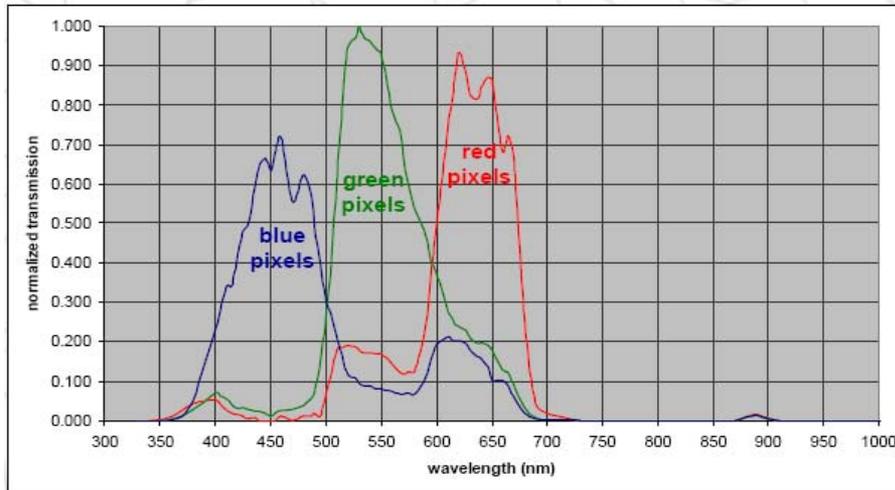
“Perfect”

Bayer  
Interpolation

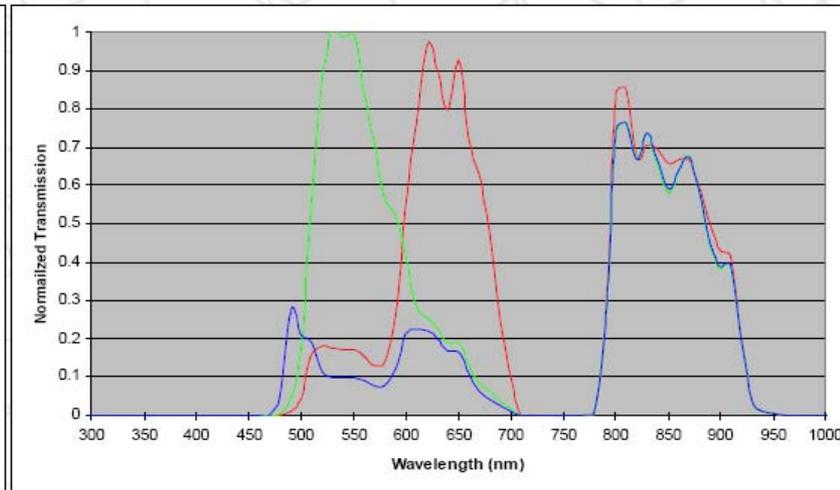
# 4-Color with Bayer Array

- Bayer patterns only have R,G,B
- All CCDs can “see” Near-infrared
- Filters used to block IR or block Blue
  - ◆ Leaves R,G,B or G,R, NIR
- Less spectrally “pure”, but often acceptable

VIS Response

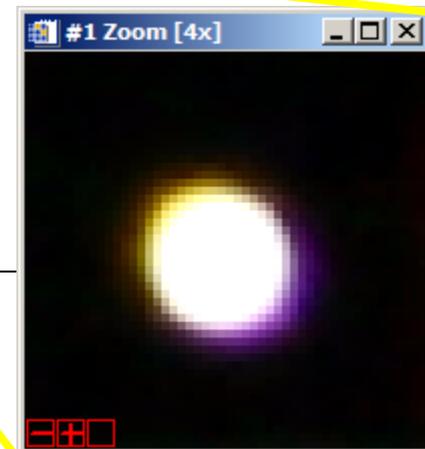
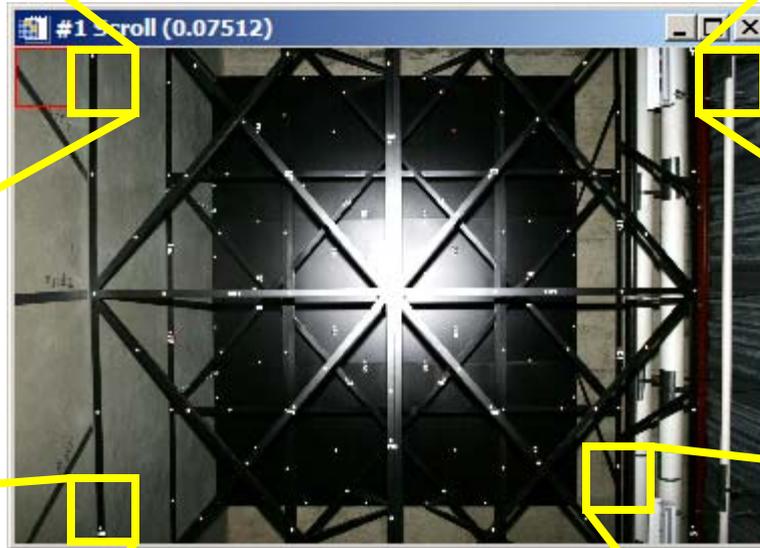


CIR Response



# Chromatic Aberration

- Note how colored fringing always radiates out from center



- Blue distorted farthest away
  - ◆ Blue fringe on "outside" of dot
- Red is least distorted
  - ◆ Red fringe on side of dot toward image center

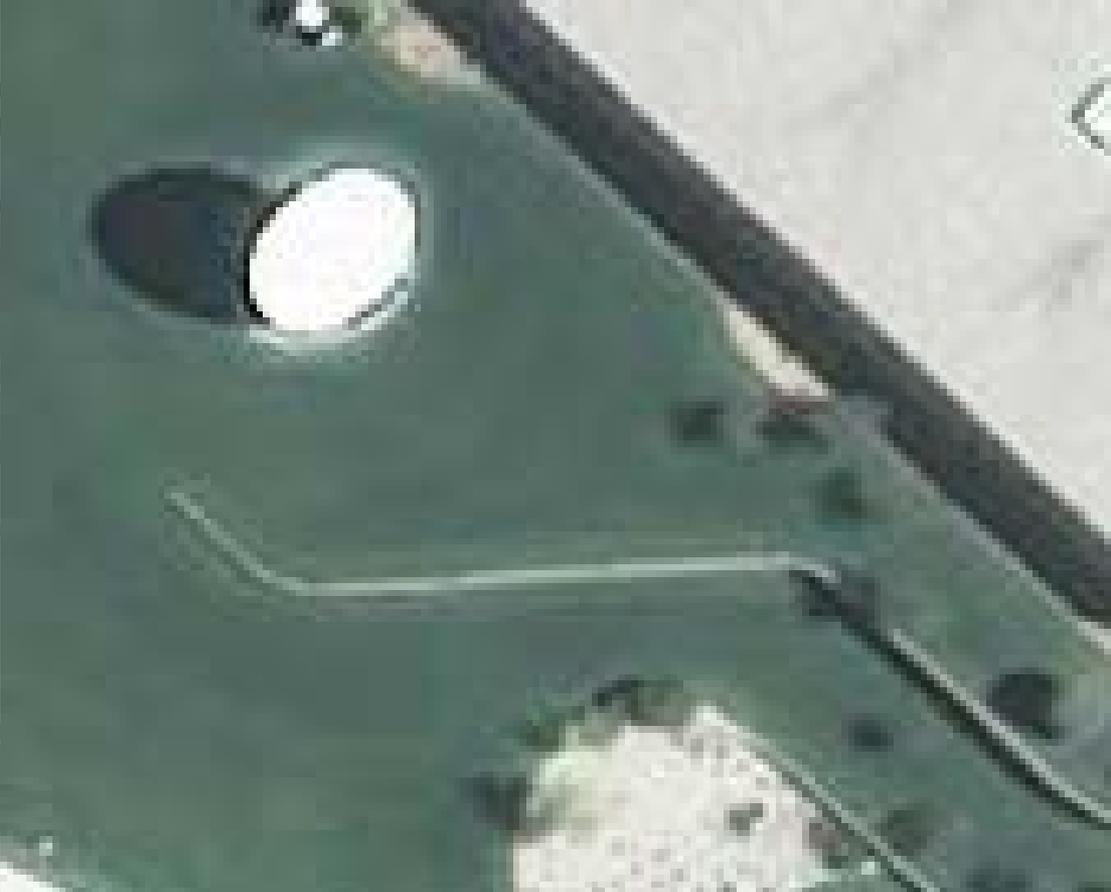
# Multiple-Camera Spectral

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- **Independent monochromatic spectral images**
  - ◆ Four cameras, each filtered to one “color”
  - ◆ Four sensors image same target
- **Merged to form final multispectral image**
  - ◆ “Color” (RGB), “Color-infrared”, 4-band VNIR
  - ◆ Ideally all are collected at same GSD
  - ◆ “Pan sharpened” is another option
- **All involve some degree of resampling**
  - ◆ Minor loss of resolution, spectral “purity”
  - ◆ Pan sharpening artifacts?
- **Good resolution, spectral content, less aberration**
- **Can do electronic FMC - forward motion compensation**
- **More costly, more calibration, more processing**



# Aerial Image of



# Applanix Dual-Cam

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- Applanix DualCam answers problems of 4-band imagery with Bayer arrays
- Uses two cameras:
  - ◆ 1<sup>st</sup> Camera: RGB Bayer array
  - ◆ 2<sup>nd</sup> Camera: Monochromatic near-infrared
- Imagery from two cameras is merged into final product



# LIDAR:

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- **Lidar is coming on strong**

- ◆ More applications being developed
- ◆ Often used in conjunction w/ medium-format cameras

- **Is Simultaneous Lidar & Imagery Beneficial?**

- ◆ It Depends!
  - Benefits Medium-format with terrain info
  - For processing it is nice to have imagery near-time to lidar (weeks, months), but not necessarily simultaneous

- **Most advantages/disadvantages are in the business model**

- Lidar can be flown at night
- Cost of aircraft, complexity of planning, executing



# USGS/IADIWG Type Certification

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- **Four systems have been certified to date:**

- ◆ Applanix DSS-322\*, -422\*, -439\*
- ◆ Intergraph Z/I DMC
- ◆ MS Vexcel UltraCamD & UltraCamX
- ◆ Leica: ADS40 w/ SH40, SH52, & SH52

- **Each company has new cameras not yet certified:**

- ◆ Applanix DSS DualCam\*
  - ◆ Intergraph RMK D\*
  - ◆ MS Vexcel – UltraCamXp & UltraCamL\*
  - ◆ Leica ADS80 w/ SH81 & SH82; and RCD105\*
- (\* Denotes medium-format)

# Type Certifications to come?

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- **Hanging in the wings?**

- ◆ DiMAC
- ◆ Airborne Data Systems
- ◆ Jena Optronik
- ◆ Pictometry

- **Recently contacted USGS:**

- ◆ Merrick & Co., Aurora, CO
- ◆ GSI Inc., Rochester, NY
- ◆ M7 Visual Intelligence, Houston, TX
- ◆ Icaros Geosystems, Israel

- **Some interesting new ideas:**

- ◆ Made-for-aerial systems, thermal infrared, etc.



# Sensors Around the World

- From manufacturers, as of Fall '08

\* Leica has not yet provided breakdown by country

\*\* Vexcel has not yet provided worldwide totals

- Compare with ~200 film cameras operating in North America

	Applanix DSS	Intergraph DMC	Leica ADS40	Vexcel UltraCam
Worldwide	120 sold, 90 operational	76	70-80	**
US	30	22	*	10
Canada	11	1	*	4



# New Technologies - Observations

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- **Many new cameras are being introduced!**
  - ◆ Getting to be a lot of competition out there
- **Large Format “has been a bloodbath out there”**
- **Important difference between “camera” and “system”**
- **Larger chips are biggest single “growth”**
- **Most new systems are variations on existing tech**
- **Some queries about “new” technologies**
  - ◆ Thermal, multi-/hyper-spectral, etc.
  - ◆ Business case hinders development
- **Focus is on competition in a business environment**
  - ◆ Not technology



# Random Observations and Thoughts

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- **Is “Large Format” stagnating?**
- **Very few announcements of new “large format”**
- **Sensors are cheap, even at a million bucks!**
  - ◆ Processing systems, timeliness, etc. are also big drivers
  - ◆ Many sensor vendors now focusing on processing
- **Smaller formats are coming on strong!**
  - ◆ Cheaper cameras, cheaper airplanes, very tempting!
- **NASA using medium-format cameras – up to 60,000 ft!**
- **Lots of new capabilities - lots of new “specifying” needed**
  - Pan sharpening? 3-band, 4-band? Spectral requirements

# COTS - A Need for Further Research

- **Large format are well understood and Europeans are looking into professional MFDCs.**
  - ◆ But many people are trying to use “other” systems
  - ◆ Cost for off-the-shelf cameras is terribly tempting
  - ◆ But not designed for aerial use!
- **Can they do they job? Yes? No? Sometimes?**
  - ◆ What are those “Sometimes”?
  - ◆ How does a contracting officer know if this proposal can meet their needs?
- **EROS has calibrated 40+ COTS cameras so far**
  - ◆ More research needed – vibration, stability, repeatability
  - ◆ What is needed to turn these into aerial mapping-grade system?