

August 13, 2004
13th Annual Undergraduate Research Symposium

*Boresight Calibration of the WASP Airborne
Mapping Camera System*

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R·I·T

**Chester F. Carlson Center for Imaging⁰
Science**

Presentation objective

- Give an overview of the Wildfire Airborne Sensor Program, WASP
- Show the importance of the boresight calibration method for aerial photography in general and for the WASP
- How WASP is handling the boresight calibration

Overview about the Wildfire Airborne Sensor Program

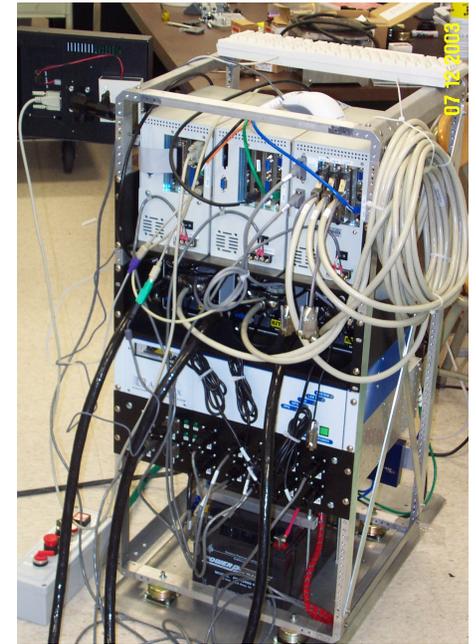
- WASP's objective
 - improve current methods used to detect fire in forest areas
- How to attain
 - set of cameras connected to a GPS and computer
 - mount equipment on small size plane and fly over forest
 - cameras are shot every 4 or less seconds
 - images are processed in real time on the plane

WASP Accomplishments

- Test flights over RIT
- Flight over controlled burn in Ohio
 - fire propagation model
 - high resolution DEM, digital elevation model
- Rewriting the acquisition system and plug to
 - image-to-image registration
 - georeference
 - mosaicing modules
 - fire detection

WASP Hardware

- GPS and IMU or Inertial Measurement Unit
give cameras position and orientation
- Gimbal - swing about 60 degrees to increase swath
- Airborne Data Processor or ADP
- 16 mega pixel visible camera – region overview
- Three infrared cameras - core fire detection
 - short wave 0.9 to 1.7 μm
 - medium wave 3.0 to 5.0 μm
 - long wave 8.0 to 9.2 μm

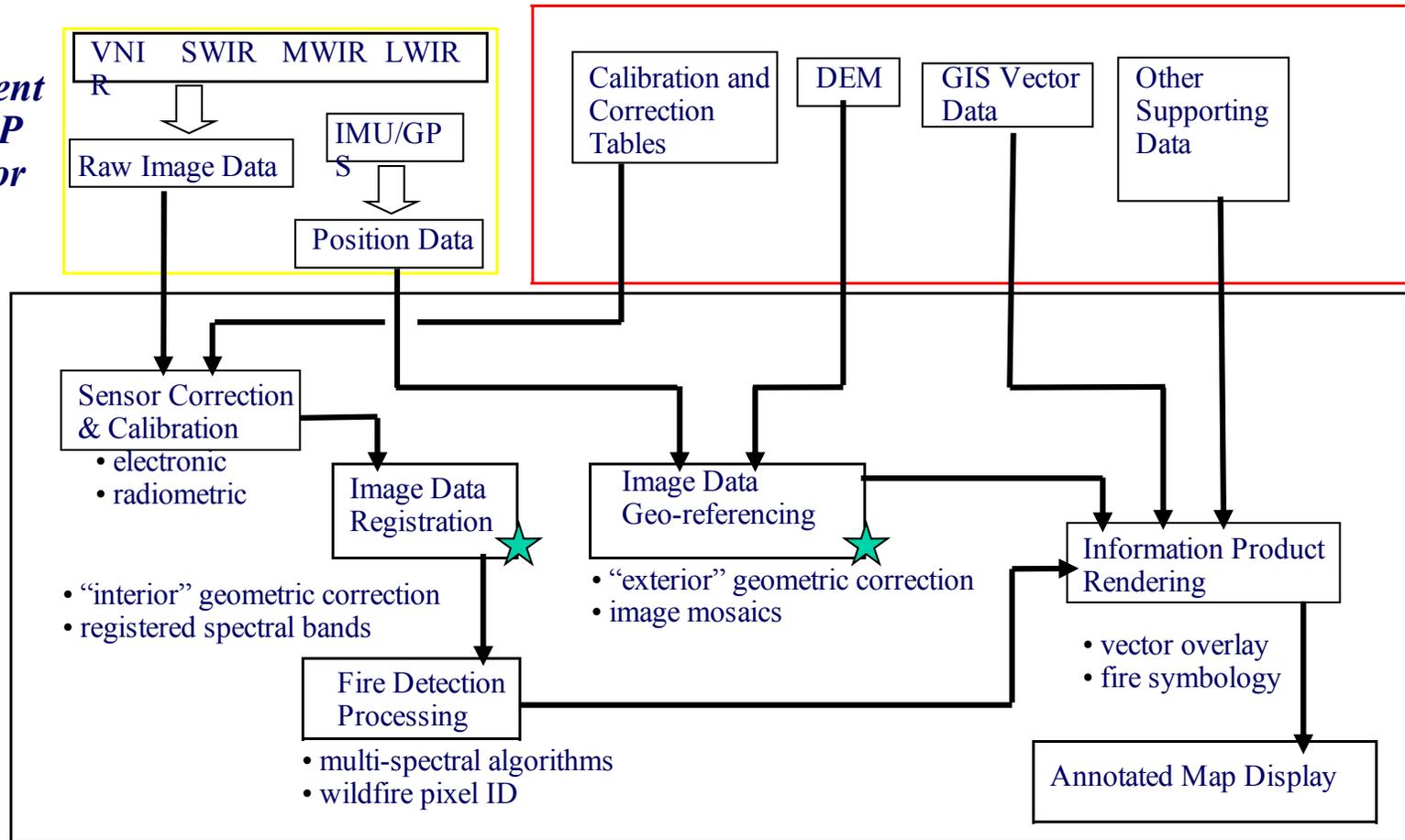


Overview of capturing process

Wildfire Mapping Sensor (System Input)

Stored Databases “Electronic Footlocker”

*Current
WASP
Sensor*



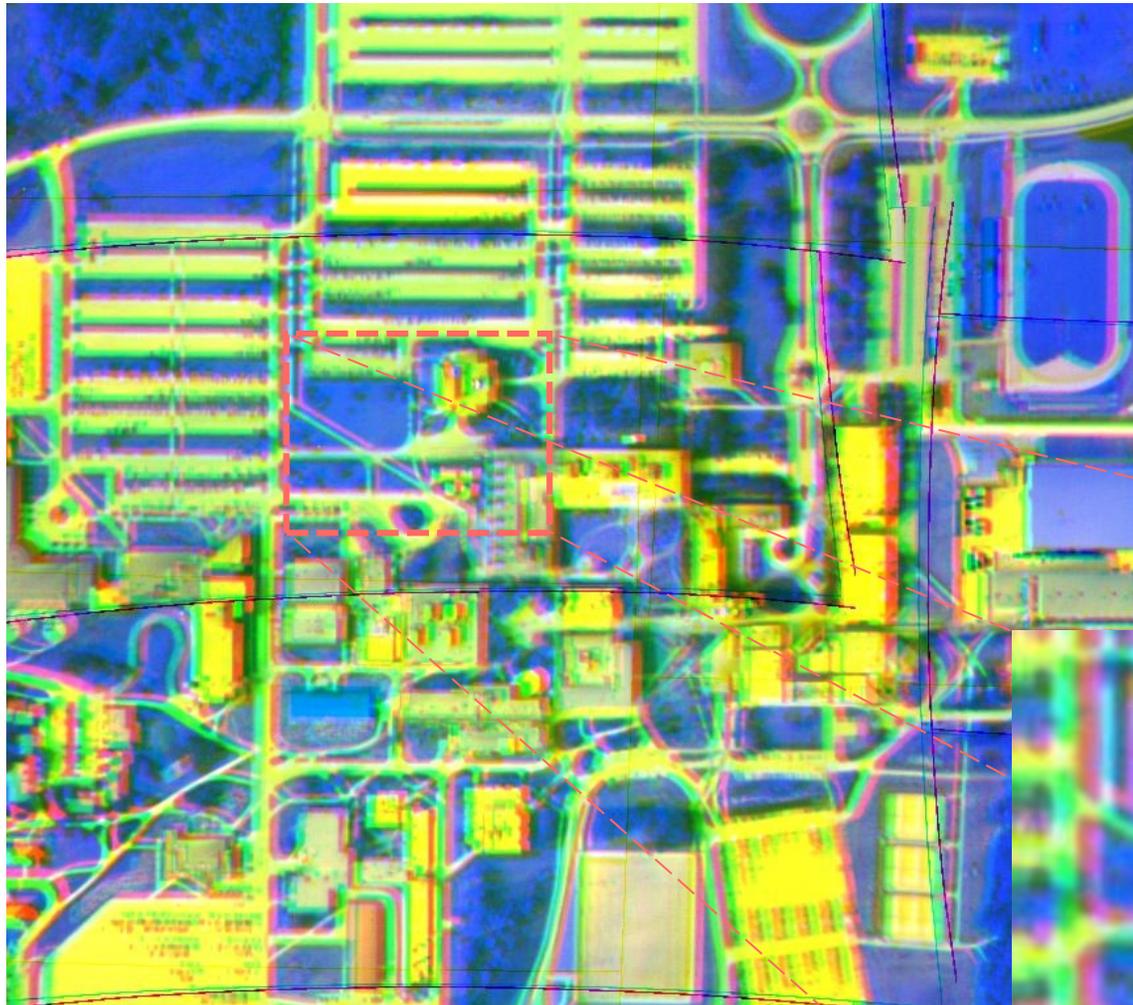
*WASP Airborne Data Processor
Automated Processing Flow*

Airborne Data Processor

Why boresight

- Boresight is the relation between camera and Inertial Measurement Unit, IMU
- Boresight is a crucial for image to image registration. The images need to stack on top of each other so their pixels represent the same ground feature
- Boresight allows the creation of high resolution image-maps to locate burn areas

Band to Band Registration without Boresight



Band Assignment

LWIR (long wave infrared) **RED**
MWIR (mid wave infrared) **GREEN**
SWIR (short wave infrared) **BLUE**

- 640 by 512 pixels
- 25 micro meter pixel size
- 16 bit images

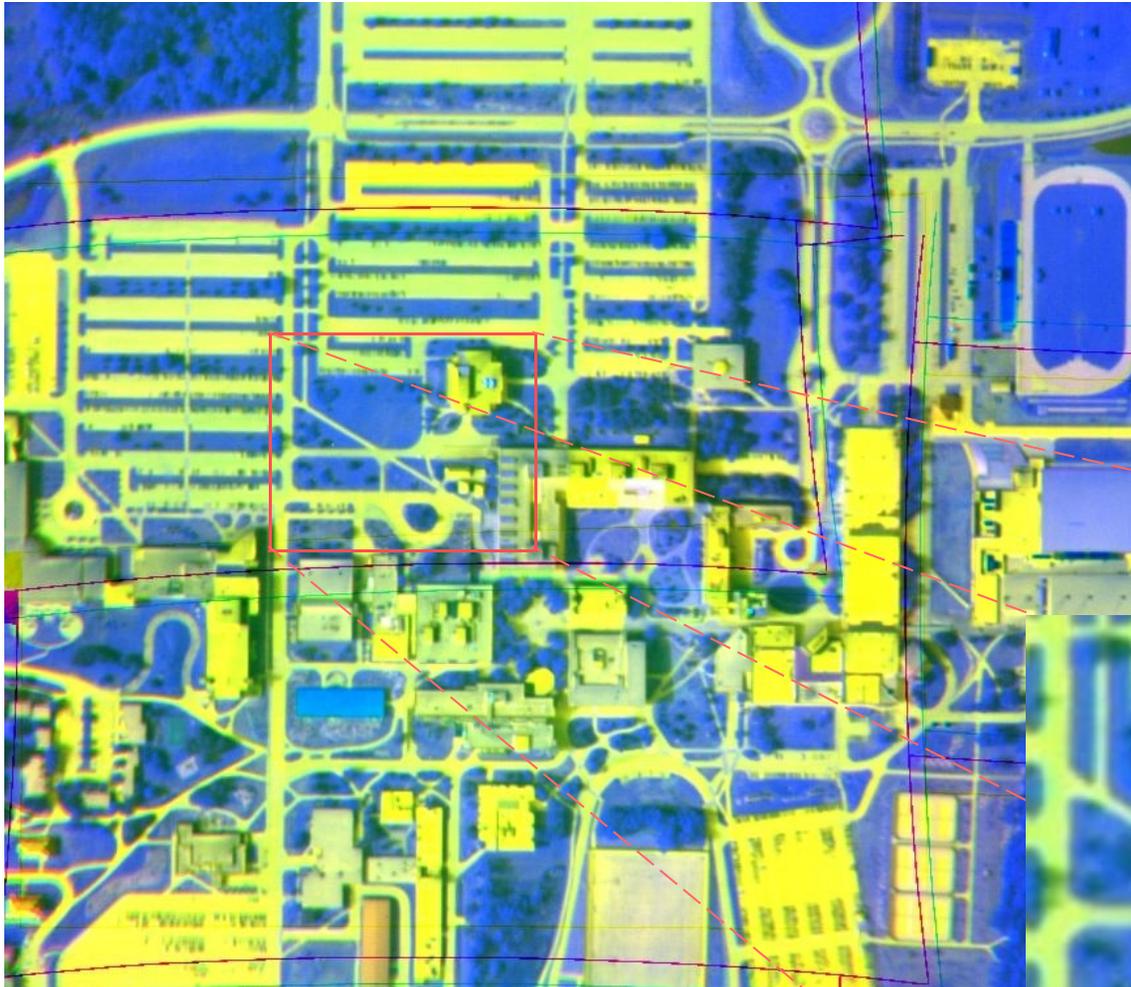


Band to Band Registration with Boresight

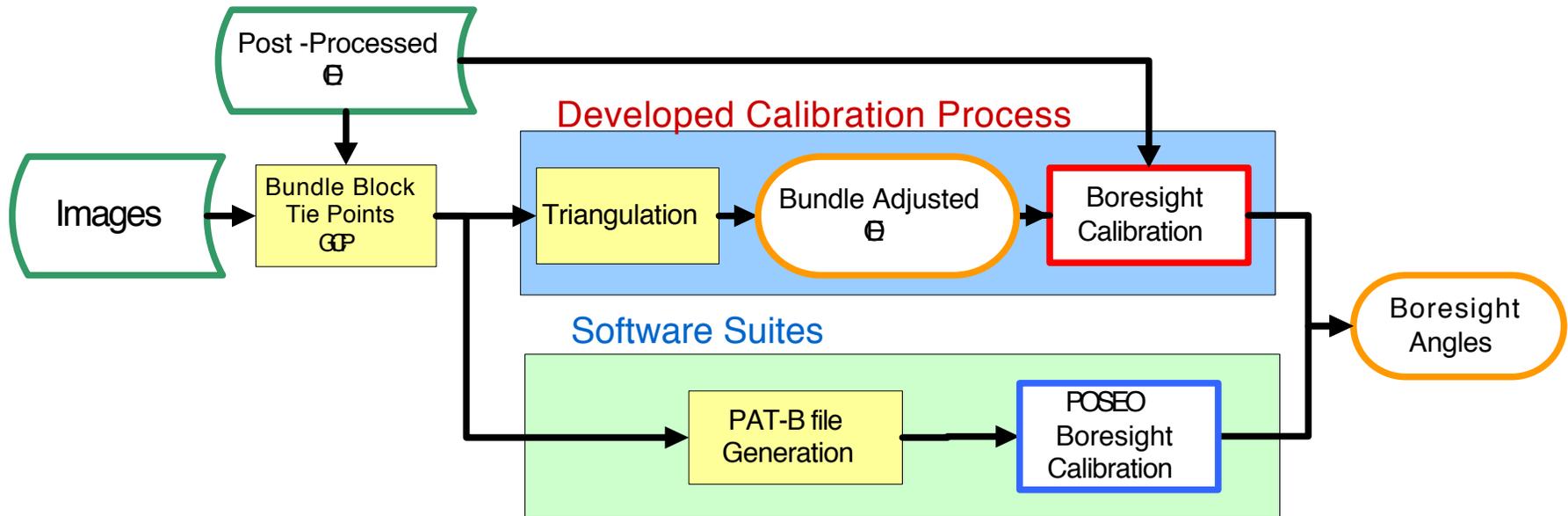
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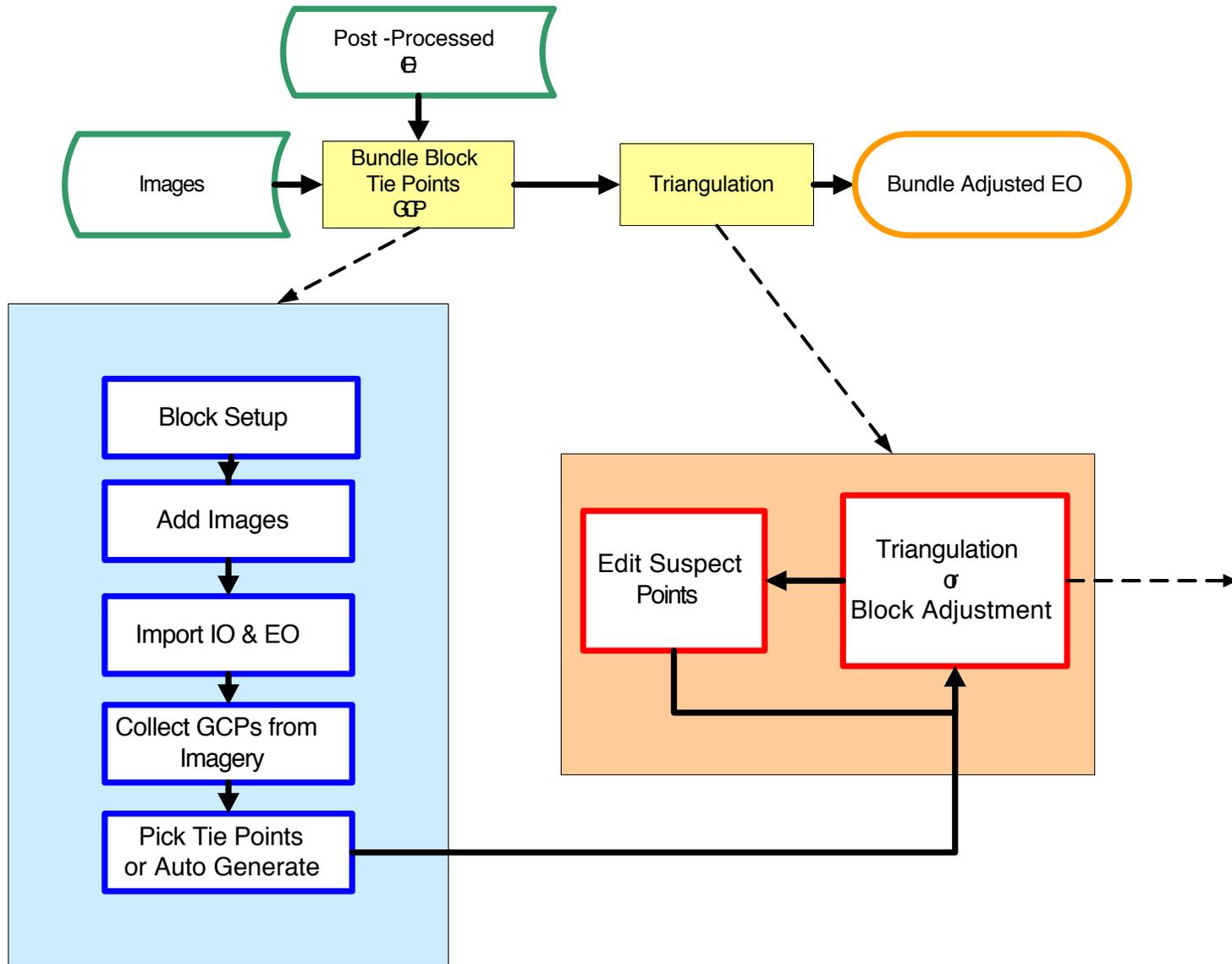
- 640 by 512 pixels
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- 16 bit images



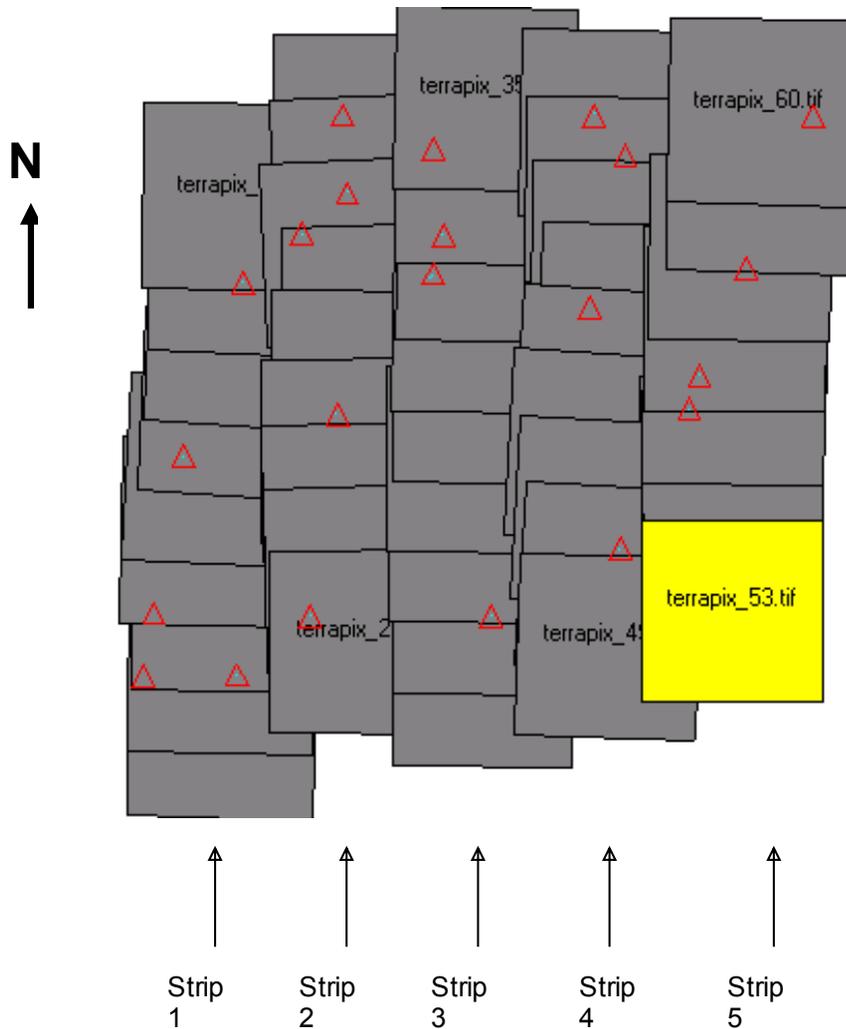
Deriving the boresight



Triangulation – [M]AT



Block Diagram with GCP

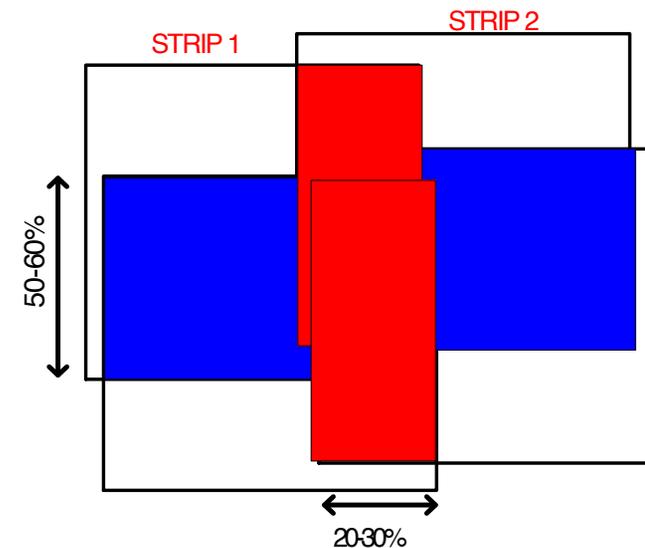


 **GCP**
[Ground Control Points]

§ **22 GCPs**
§ **43 Images in 5 strips**

Requirements

§ **GCP in beginning and end of strip**
§ **Opposite flying directions**
§ **Minimum of two strips**



IO and EO

- Interior Orientation or IO
 - Focal length
 - Radial lens distortion (K_0 , K_1 and K_2)
 - Pixel size
- Exterior Orientation or EO
 - $(x, y, z, \omega, \varphi, \kappa)$

Adding Points

Point Measurement (Left view: terrapix_19.tif Right view: terrapix_18.tif)

Use Viewer As Reference

Left View: terrapix_19

Apply Image Shift

50 0 100

50 0 100

Apply Reset

Right View: terrapix_18

Apply Image Shift

50 0 100

50 0 100

Apply Reset

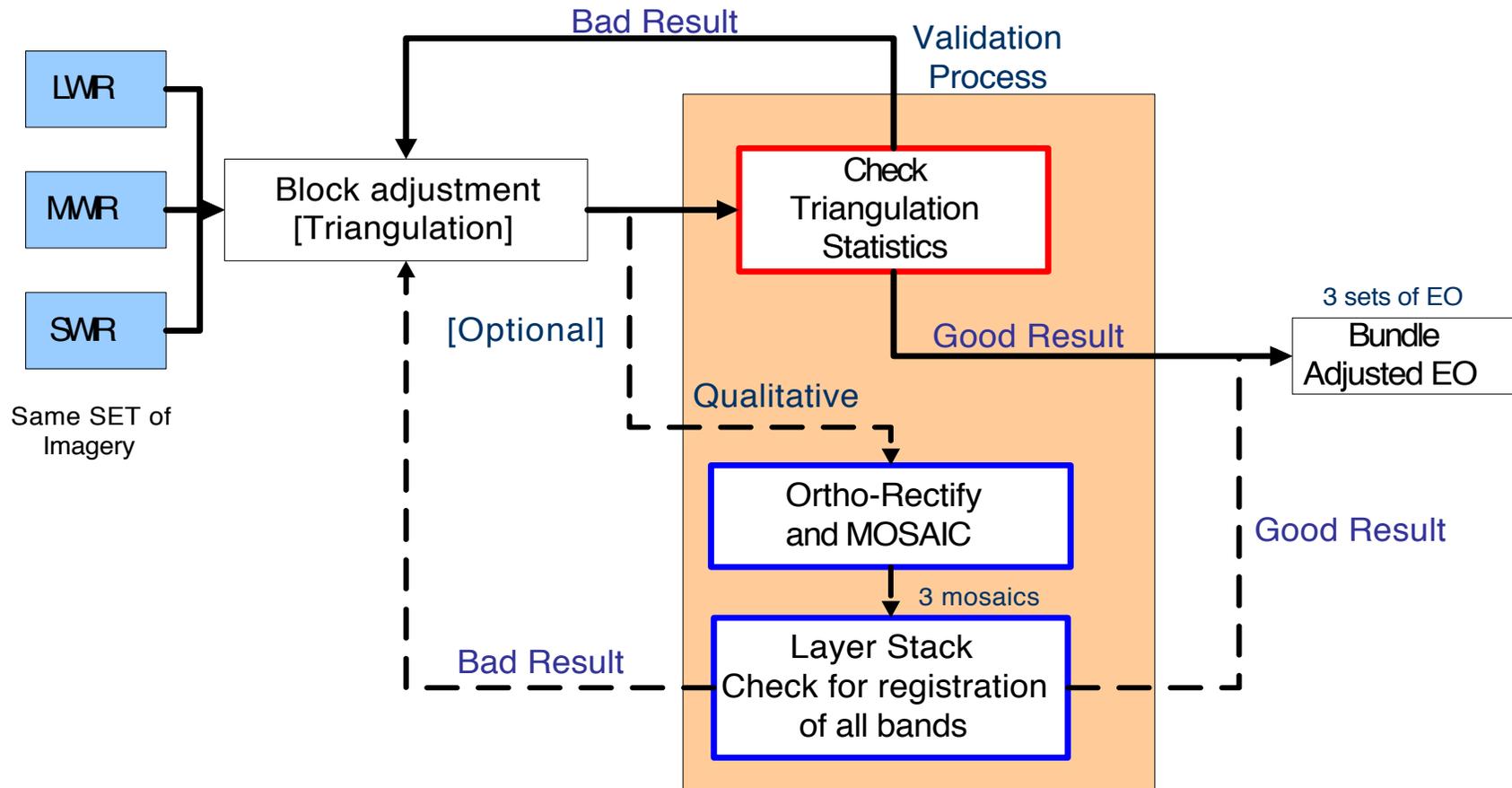
Horizontal: none

Vertical: none

Point #	Point ID	Description	Type	Usage	Active	X Reference	Y Reference	Z Reference
671	671	>	None	Tie		284063.577	4773849.101	121.437
672	672		None	Tie	X	283511.522	4774640.153	126.754
673	673		None	Tie	X	283940.818	4774612.610	137.004
674	674		None	Tie	X	283776.397	4774508.924	125.073
675	675		None	Tie	X	284124.559	4774538.473	126.852
676	676		None	Tie	X	283374.780	4774386.643	136.540
677	677		None	Tie	X	284121.147	4774354.806	120.650
678	678	>	None	Tie	X	283920.022	4774330.443	122.630

Image #	Image Name	Active	X File	Y File
1	terrapix_59	X	2788.749	1592.858
2	terrapix_60	X	2804.726	3101.064
3	terrapix_58	X	3153.124	67.396

Bundle Adjusted EO Validation



Deriving the angles from the orientation matrix

The orientation matrix M is derived from M_ω , M_Φ and M_K , which are the rotation matrices with respect to x , y and z axis:

$$M = M_\omega M_\Phi M_K$$

$$M = \begin{bmatrix} \cos \Phi \cos K & \cos \omega \sin K + \sin \omega \sin \Phi \cos K & \sin \omega \sin K - \cos \omega \sin \Phi \cos K \\ -\cos \Phi \sin K & \cos \omega \cos K - \sin \omega \sin \Phi \sin K & \sin \omega \cos K + \cos \omega \sin \Phi \sin K \\ \sin \Phi & -\sin \omega \cos \Phi & \cos \omega \cos \Phi \end{bmatrix}$$

Omega (roll), phi (pitch) and kappa (yaw) are derived from the following relationships:

$$\begin{aligned} \sin \Phi &= m_{31} \\ -\tan \omega &= \frac{-\sin \omega \cos \Phi}{\cos \omega \cos \Phi} = \frac{m_{32}}{m_{33}} \\ -\tan K &= \frac{-\cos \Phi \sin K}{\cos \Phi \cos K} = \frac{m_{21}}{m_{11}} \end{aligned}$$

Deriving the boresight matrix $[\Delta M]$

Transformation to be applied to post processed exterior orientation (IMU attitude with differential GPS) that will yield the orientation of each camera

This transformation is a matrix multiplication of the unknown boresight matrix (ΔM) matrix and the known IMU attitude

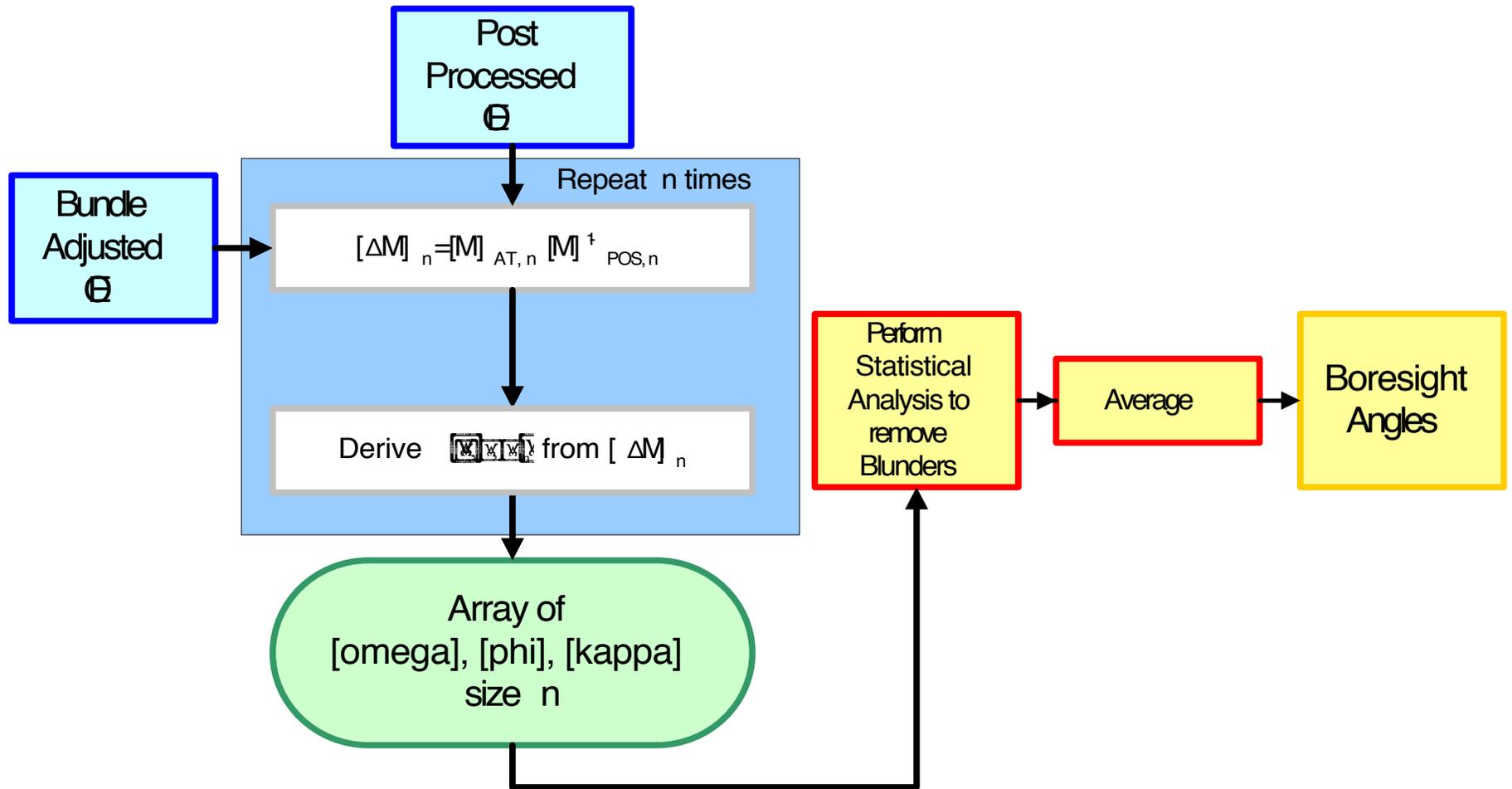
$$[M]AT = [\Delta M][M]POS$$

Multiplying both sides by $[M]POS^{-1}$ yields

$$[\Delta M] = [M]AT \times [M]POS^{-1}$$

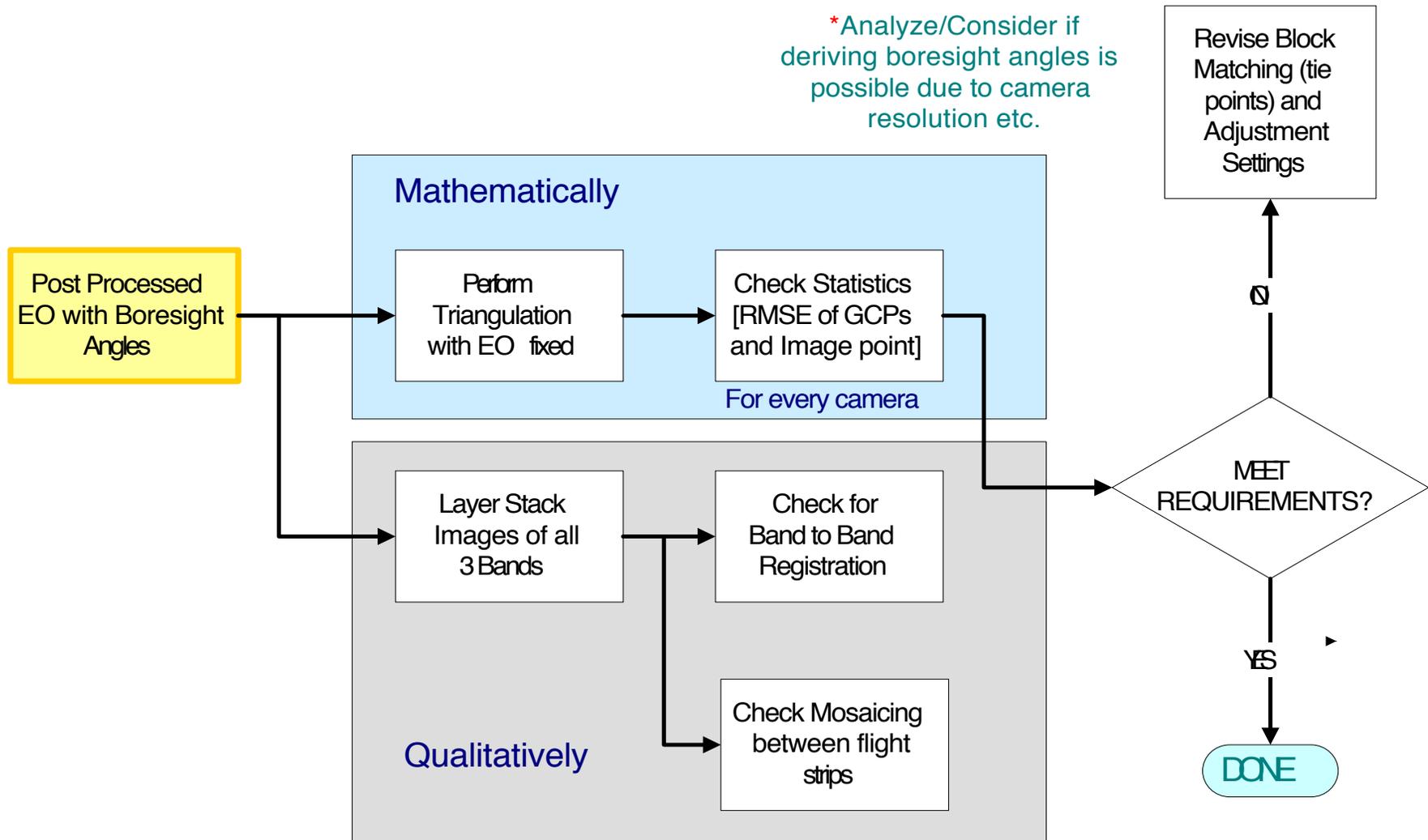
- $[M]AT$ is the orientation matrix from Aerial Triangulation
- $[\Delta M]$ is the transformation matrix
- $[M]POS$ is the IMU's attitude

Deriving the Boresight Angles



Validating the Derived Boresight Angles

*Analyze/Consider if deriving boresight angles is possible due to camera resolution etc.



What is next

Limitations and areas for improvement:

- How to take GPS accuracy deterioration high altitudes into account.
- Not accounting for lever arm between IMU and cameras
- There are other more robust triangulation software
- Picking tie points in IR imagery is error prone (distortion and low resolution)
- Hard to keep consistency when terms and signs are defined differently among the literature and software vendors

Future steps:

- Use data sets over other regions to validate boresight
- Assess fire detection algorithm's performance using boresight corrected imagery
 - Real time GPS data (without differential correction)
 - Vary flying height (4k to 10k)
- Resort to other registration techniques if boresight correction doesn't produce adequate results

Who is involved

Chester F. Carlson Center for Imaging Science

Funded by



US Forest Service as potential user

Corporations

The Leica logo, written in a red, cursive font.

Local Geosystems

The indigo logo, featuring the word "indigo" in a blue, lowercase font with a small square icon to the right.

• Pictometry, Pixel Physics, LightForce Technology Inc, Landcare Aviation
Consultant

• Don Light

Educational institutions

• University at Buffalo, State University of New York,
Cayuga Community College

Questions?



Thank you!

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