

The New Rig Camera Process in TNTmips Pro 2018

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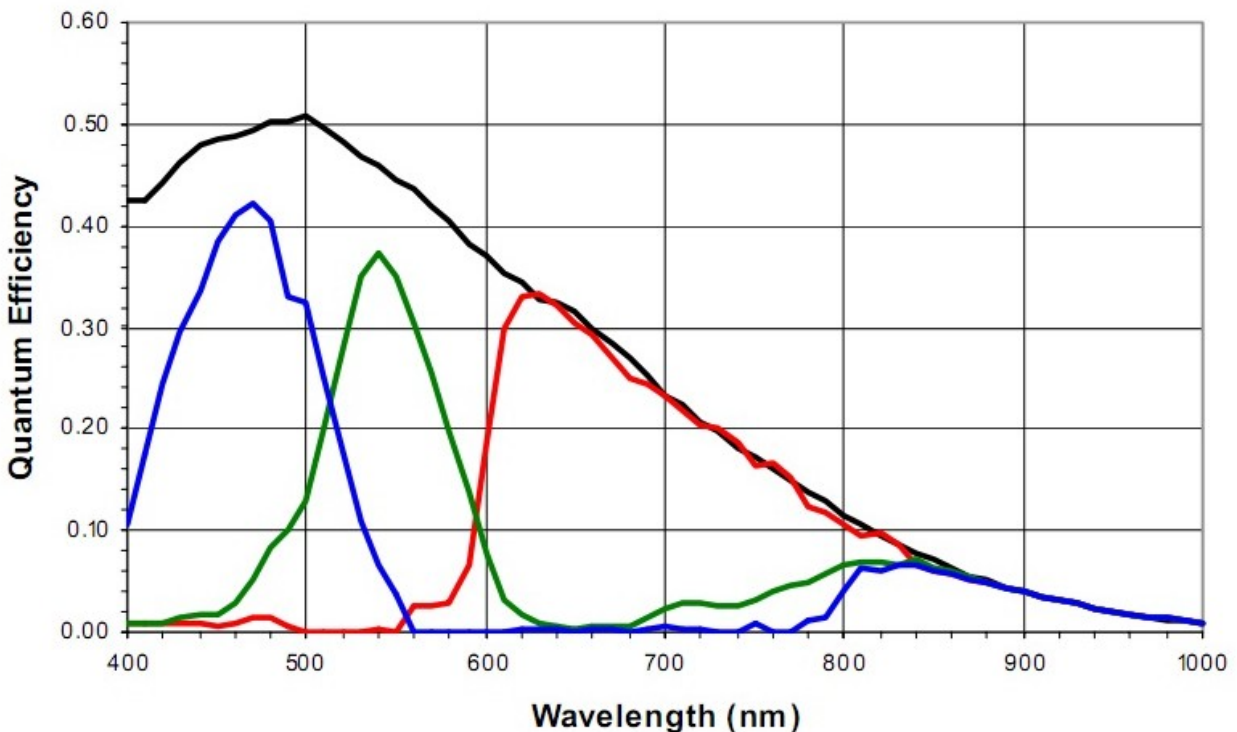
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Kinds of Digital Cameras for Drones

Two kinds of multispectral digital imaging systems are available for drones:

- Single-lens / single-camera **Bayer-pattern** systems
- Multiple-lens / multiple-camera **rig** systems

Each detector in a digital camera is sensitive to a wide range **electromagnetic radiation (EMR)** wavelengths. An example of the **unfiltered** sensitivities of a typical detector is shown by the **black line** in the plot below. Adding filters will change the spectral sensitivity of the digital data.



The units for wavelength in this plot are **nanometers (nm)**. **Quantum efficiency (QE)** is how efficient the detector is in responding to the radiant energy of the photons that are incident on it. The QE of this detector extends to wavelengths that are shorter than 400 nm ... into what is known as the **ultraviolet (UV) region** of the EMR spectrum.

The wavelengths in this plot are usually broken down in to **three named spectral regions**:

- The **Visible light** region (visible to humans): **400 to 700 nm**
- The **Red-edge radiation (RE)** region: **700 to 760 nm**
- The **Near-infrared radiation (NIR)** region: **700 to 1000 nm** (goes out to 1400 nm)

Panchromatic Images

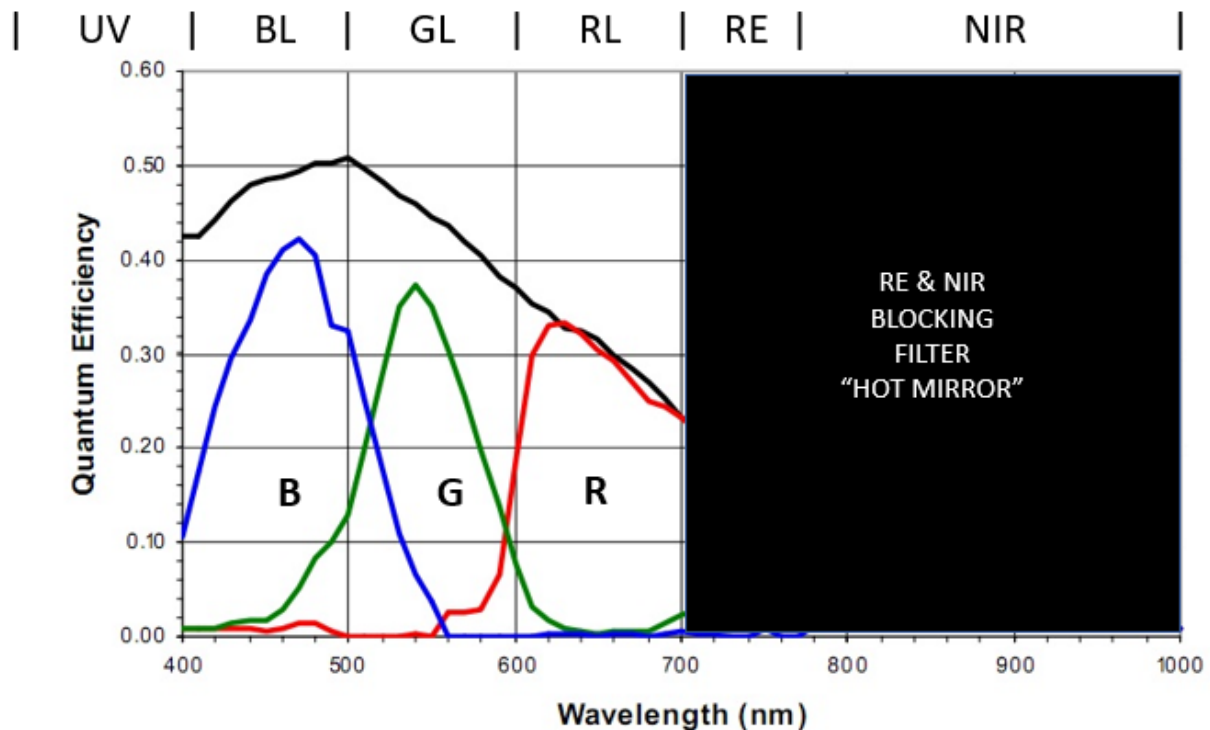
If **no filter** has been placed in the optical path, between the lens and the focal plane, then the digital images collected by the camera are called **panchromatic (PN)** images. However, to improve the quality of the PN imagers, many panchromatic cameras will have a filter that blocks EMR having wavelengths shorter than 500 nm ... a way to reduce the effects of haze on the captured images (which affects UV and blue light EMR) ... and another filter to block wavelengths longer than 700 nm ... a way to remove the unwanted influences of RE and NIR EMR on the resulting PN image.

Natural Color Bayer-Pattern Camera

If the digital camera is a **natural color (NC)** camera, then it will have a filter over each detector. These filters each pass a limited range of wavelengths ... a different pass range for each kind of filter. There usually are three kinds of filters as follows:

- **A Blue light (BL)** pass filter: The blue line in the graph on the previous page
- **A Green light (GL)** pass filter: The green line in the graph on the previous page
- **A Red light (RL)** pass filter: The red line in the graph on the previous page

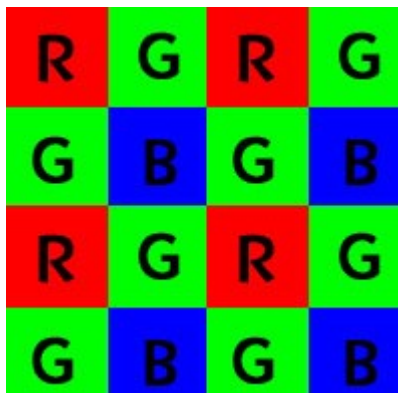
For a NC camera, there also will be a filter in the camera that blocks EMR having wavelengths longer than 700 nm, i.e., that blocks both RE and NIR EMR. This changes the QE as shown below:



This overall RE & NIR blocking filter is called a “hot mirror” ... a name that seems to come from the notion that infrared radiation is related to something hot (RE and NIR has nothing to do with the temperature of things). The “hot mirror” filter is necessary for a NC camera since, as you can see in the three plots on the previous page, that each of the three BL, GL, and RL filters allows some RE and NIR EMR to pass to the detector.

Note that each of these three NC filters have peak-transmissivities wavelength at about 480, 540, and 620 nm, respectively. These three peak-transmissive wavelengths correspond to colors of the rainbow called cyan, green, and yellow. Nevertheless, we refer to these filters as BL, GL, and RL filters.

A single-lens / single-camera Bayer pattern imaging system arranges the three filtered kinds of detectors in a checkerboard pattern like the one shown below:



The symbols here (R, G, and B) stand for RL, GL, and BL detectors. When a Bayer-pattern camera collects an image ... called the RAW image, a digital number (DN) is saved for each of the detectors. So, there are DN values for all of the R detectors (25% of the total number of detectors), there are DN values for all of the G detectors (50% of the total number of detectors), and DN values for all of the B detectors (25% of the total number of detectors).

These DN values are saved usually as an unsigned 16-bit integer ... having possible integer values from 0 to 65,535.

Later in the processing flow, each pixel will get a full set of R, G, and B values.

If the target pixel is a B pixel, then the matching R value comes from an average of the four R values in the 8 surrounding pixels, and the matching G value comes from an average of the four G values in the 8 surrounding pixels.

If the target pixel is a G pixel, then the match R value comes from an average of the two R pixels in the 8 surrounding pixels, and the match B value comes from an average of the two B values in the 8 surrounding pixels.

If the target pixel is a R pixel, then the matching G value comes from an average of the four G values in the 8 surrounding pixels, and the match B value comes from an average of the four B values in the 8 surrounding pixels.

The process of making a complete set of R, G, and B values for each Bayer-pattern pixel is called Bayer interpolation or Bayer de-mosaicking.

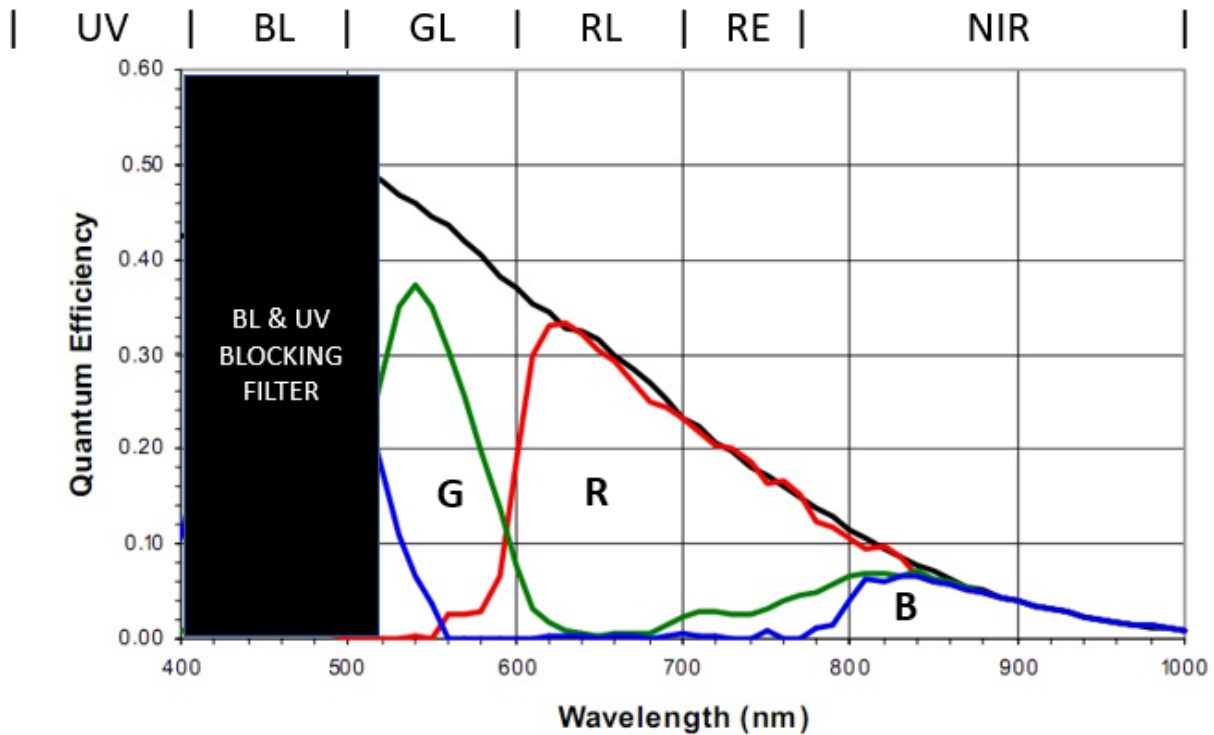
Note that the resulting three R, G, and B values do not come only from the small area associated with the pixel; rather, they come from the 9 pixels in the Bayer-pattern array. So, the spatial resolution of a Bayer-pattern image is not the same as the Ground Spacing Distance (GSD) between adjacent pixels.

The spatial resolution of a PN image is the same as the GSD between adjacent pixels.

Color Infrared Bayer-Pattern Camera

If the RE and NIR blocking filter is removed from a Bayer-pattern NC camera, and if a new filter is inserted to block one of the visible color regions ... block BL or block GL or block RL ... then the Bayer-pattern camera has been “converted” to be a kind of **color infrared (CIR)** camera.

For example, if the blocked visible region is the BL region, then the QE plus filter spectral curves look like the following:



The G DN values from this camera come mostly, but not entirely, from the GL part of the spectrum. The RE and NIR parts of the spectrum also contribute EMR to the G detector.

The R DN values from this camera come mostly, but not entirely, from the RL part of the spectrum. But, R also includes quite a bit of RE and some NIR.

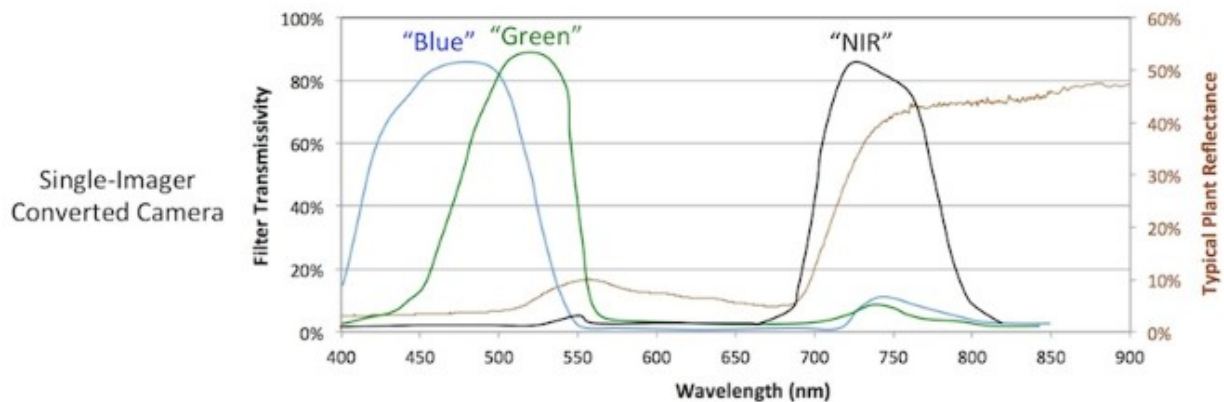
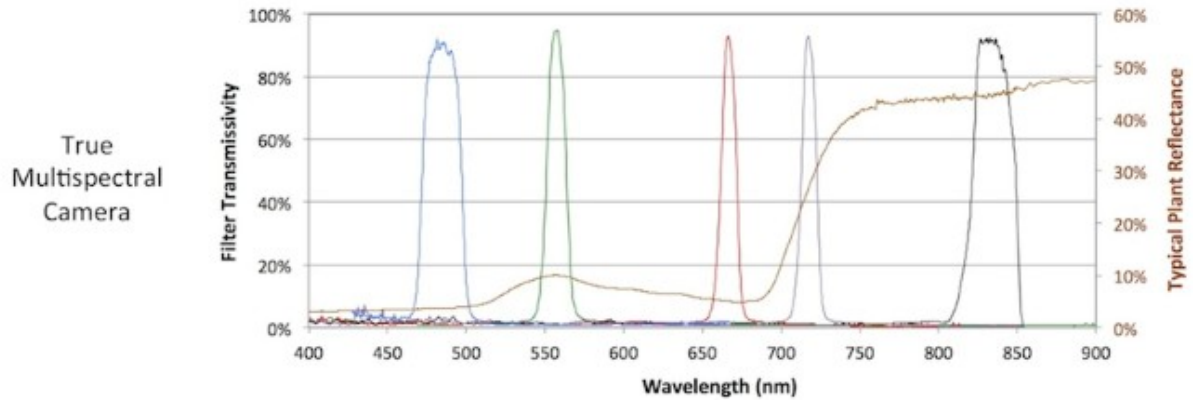
The B DN values from this camera come mostly from the NIR part of the spectrum. Some GL also gets into the B values.

So, such a modified NC Bayer pattern camera does capture GL, RL, and NIR ... but not in a very clean way.

Multispectral Rig Cameras

Every satellite based multispectral imaging system uses a separate set of detectors for each spectral band image capture. And, these detectors are filtered by narrow-band pass filters that keep other wavelengths of EMR from adding to the DN values.

In the case of drone-based cameras, one frame camera is used for each spectral band. Consider, for example, the cameras in a MicaSense RedEdge Model 3 True Multispectral camera. The filters in each of these five cameras capture EMR as shown in the plots below:



Below these curves is another configuration for a modified Bayer-pattern camera that is designed to serve as a kind of NDVI camera. Note that here the blocking filter has been placed in the RL part of the spectrum. Then, the B readings relate to BL, the G readings relate to GL, and the R readings relate to RE plus some NIR (inappropriately labeled here as "NIR").

The BL and GL images come from highly overlapping spectral regions. So, at best, the data from this camera could support the making of a Green NDVI index (Green Normalized Difference Vegetation Index). However, this is more like a normalized difference vegetation index based on GL and RE.


Dealing with Rig Camera Images

Since each spectral band image from a rig-camera imaging system, such as from a MicaSense RedEdge Model 3 camera, is taken by a separate camera, the resulting saved images will not likely be co-registered with each other.



Also, the exposure time and/or ISO (digital gain) of each camera has been altered by the rig camera system from frame to frame so that the DN values are kept within the allowed range of DN values in the TIFF files ... unsigned 16-bit integer values ... allowed values from 1 to 65,535. For the MicaSense RedEdge camera, these saved values are really 12-bit values that have been expanded by multiplying each of them by 16.

► **What We Do with “Raw” Drone Image Files:**


A Typical “Raw” Drone Image





RGB or NDVI Bayer
Single Camera ❌





The Related ROAM™ Processed Image





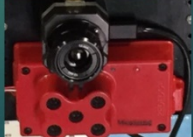
Rig True Multispectral Camera ✅



Duo RGB + Thermal Rig Camera ✅



Multispectral with Thermal Rig Camera Not Yet Made ❌❌



MicrolImages has added a new process to the TNTmips Pro 2018 software called the “Rig Camera Alignment & Exposure Balancing” process. This process can be applied to the TIFF files that have been saved by a MicaSense camera or a MAPIR camera (the green cameras above) or to a SlantRange 3p camera.

This new TNTmips Pro 2018 process is fast. After developing resampling models, it will apply corrections for vignetting and for variations in exposure times and/or ISO settings and then resample the non-NIR images to match the NIR image. The result is an image like the one shown above on the right (which is a color infrared combination where NIR, RL, and GL has been assigned to red, green, and blue primary additive display colors). Also, this software process will create contrast-enhancement lookup tables that allow for the resampled unsigned 16-bit integer DN values to be displayed nicely. These TNTmips Pro 2018 processes are part of an overall Remotely Operated Agriculture Mapping (ROAM™) system of processes with the rest of the processes beyond the TNTmips Pro 2018 process being available from Paris Geospatial, LLC.

Options in the TNTmips Pro 2018 Rig Camera Process

When you run this process, you will be presented with a list of data from the EXIF parts of each TIFF file, as shown below:

Frame	Longitude	Latitude	Altitude	BL EI	BL Blk	GL EI	GL Blk	RL EI	RL Blk	NIR EI	NIR Blk	RE EI	RE Blk
0001	W 121 48 07.49	N 36 42 52.06	46.07	83.3	5146	60.8	5135	148.5	5125	90.0	4976	164.3	5109
0002	W 121 48 07.77	N 36 42 52.03	47.12	83.3	5155	60.8	5132	130.5	5119	90.0	4980	146.3	5106
0003	W 121 48 07.96	N 36 42 52.01	47.94	83.3	5152	60.8	5135	130.5	5127	90.0	4980	146.3	5115
0004	W 121 48 08.20	N 36 42 51.99	48.98	83.3	5158	60.8	5127	130.5	5128	90.0	4979	146.3	5106
0005	W 121 48 08.49	N 36 42 51.97	50.14	83.3	5164	47.3	5127	130.5	5127	90.0	5003	146.3	5111
0006	W 121 48 08.69	N 36 42 51.95	50.86	58.5	5167	47.3	5136	117.0	5127	78.8	4995	146.3	5108
0007	W 121 48 08.93	N 36 42 51.94	51.87	58.5	5173	47.3	5133	117.0	5105	78.8	5000	128.3	5104
0008	W 121 48 09.17	N 36 42 51.93	52.90	58.5	5171	47.3	5131	117.0	5107	78.8	4999	128.3	5104
0009	W 121 48 09.42	N 36 42 51.92	53.91	58.5	5170	47.3	5137	117.0	5127	78.8	4995	128.3	5108
0010	W 121 48 09.66	N 36 42 51.91	54.92	58.5	5167	47.3	5143	117.0	5124	78.8	4995	128.3	5106
0011	W 121 48 09.90	N 36 42 51.90	55.92	58.5	5166	47.3	5138	117.0	5121	78.8	4998	128.3	5108

Parameters:

Output Bands: NIR RE RL GL BL | Multi-Band in Single File

Exposure Balance Vignetting correction Override Coefficient: 0.030

Adjust for variable lighting using reference band: Near Infrared

Recompute base alignment Adjust alignment for each frame

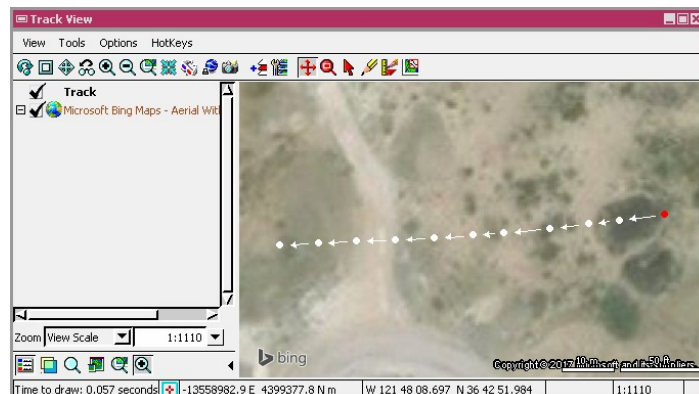
Status:

The source files could have come from several folders ... named 000, 001, etc. They need to start with those in Folder 000.

The listed metadata includes the NEW frame number, the longitude, the latitude, the altitude (above mean sea level in meters), the black (Blk) values (dark current) for each spectral band image and an **exposure index (EI)**. EI is a combination of exposure time and ISO setting. Even for this short series of ten frames, the EI values change as the drone flew over bright sand and dark water.

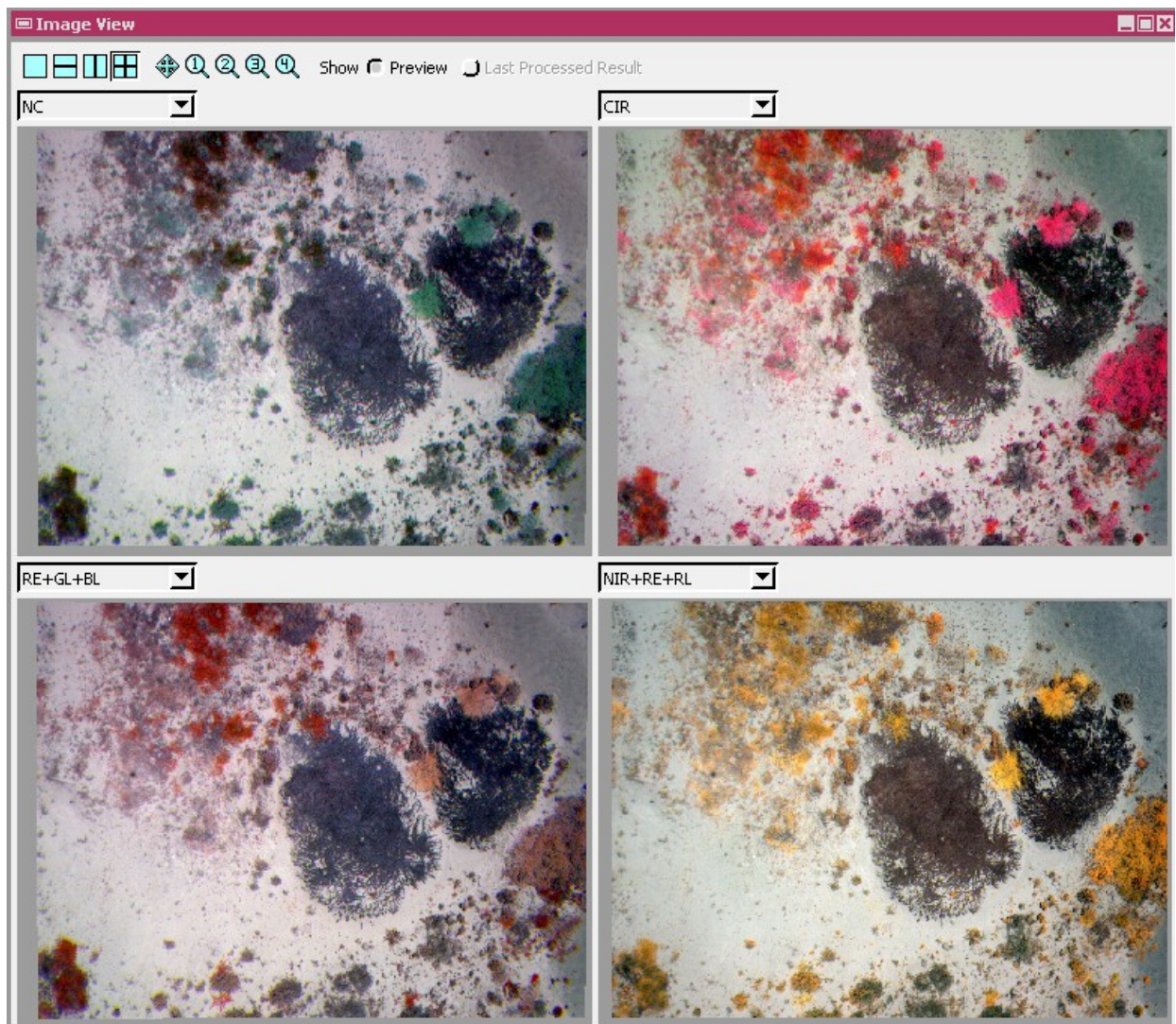
One option then is to use the **View Track...** option. It shows the locations of the GPS defined waypoints (over Bing Maps ... if you are connected to the Internet). See the illustration for these ten frames (on the right).

The red dot shows where the waypoint is for the row that is highlighted in the metadata list. In this case, this is the location of Frame 0001.



Next, you should use the **Run...** option. The process then processes all the images in the folders and produces **camera-corrected and co-registered (CR)** images. These CR images are saved in a new set of CR.tif files (in a CRTIFF folder) with a new GPSdata.csv file (for the GPS data in a format that is compatible with photogrammetry software (such as Pix4Dmapper Pro or SimActive Correlator 3D). If you are using the latter, then you need to disable one of the five images since SimActive software can handle only a maximum of four components. The Run also produces a set of CR.rvc files with the raster objects in them being linked to the images in the CR.TIFF files.

Another option is to use the **View Images...** option. It allows you to view automatically contrast enhanced combinations of the various spectral band images ... up to four combinations for each frame (as shown below).



This includes familiar combinations such as NC (Natural Color) and CIR (Color Infrared). But, you also see a couple of leaf or scene object pigmentation sensitive options such as RE, GL, and BL (as red, green, and blue) and NIR, RE, RL (as red, green, and blue).

Since this quick view images are consistent, from frame to frame, the colors that you see will also be consistent from frame to frame.

If you zoom into (say 2X), you can check to see if the co-registrations are accurate. If not, then there are options to re-do the co-registration models again (even based on one selected frame that has lots of sharp spatial features in it) ... or you can ask the process to produce a separate co-registration model for each frame.

The last option is the **Image Band Correlation** option. It works like the Image Band Correlation tool in the rest of TNTmips Pro ... including the interaction between the location in the image and the “dancing pixels” in the several scatterplots ... or the use of the Range tool to highlight the pixels that fit the prescribed ranges.

The example below includes the use of the Line tool to mark where the **Line of Bare Soils (LBS)** line is ... its intercept and slope ... in the scatterplot of **Red** values versus **Near Infrared** values. This line (with its intercept and slope values) is essential for a calibration method that I have developed so that several spectral index maps can be made from the raster values.

