HOOSIER LEGENDS:

HOW RAW IMAGE CAPTURING SHAPES PRODUCTION AND POST-

PRODUCTION OF NON-FICTION VIDEO

A CREATIVE PROJECT

SUBMITTED TO THE GRADUATE SCHOOL

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# INTRODUCTION

Produced in 2013 and 2014, the *Hoosier Legends* television series is an episodic documentary series on the Fox Sports Midwest cable channel. *Hoosier Legends* explores how RAW* image capturing can shape the production and post-production workflow of non-fiction video. The entire series consists of 36 episodes, which document the most nationally renowned names in Indiana sports. *Hoosier Legends* celebrates the history, culture, and lives of former Indiana sports heroes. In order to bring these stories to television, I decided to utilize an Ultra HD* 5K RED cinema camera as the primary production camera of choice. This choice resulted in several significant technical challenges that I had to overcome. This camera acquires video footage in an unprocessed form, referred to as RAW. Also known as direct sensor data, the footage must be processed digitally for viewing. By way of comparison, traditional cameras rely on smaller sensors that process the RAW signal internally. This signal is often heavily compressed. This internal processing and small file size makes traditional video footage easy to edit in post-production. RAW footage, however, is far more complex and requires special handling, significant amounts of storage space, and specialized workflow.

In capturing RAW data for this series, my production team was able to manipulate recorded footage in post-production with no negative effect or degradation from the original footage captured. *Hoosier Legends* required a quick turnaround time, with 1 episode being recorded each week, for 36 weeks. This workflow forced the team to be as efficient as possible. The utilization of RAW image capturing was a key part of the production and post-production workflow, it allowed the production team to shoot on a smaller budget, but still produce a professional product that rivals 35mm photochemical* film equivalency.

This project, therefore, has two central objectives. First, I wanted to explore, devise, and streamline the production to post-production process with RAW image data. Secondly, I wanted to finish a national level documentary predicated on these methods, while identifying the necessary steps to produce the documentary as efficiently and inexpensively as possible. *Hoosier Legends* explains how the use of RAW motion picture imaging can shape the production and post-production workflow in non-fiction video.

To correctly understand, my choice to implement cameras that utilized RAW data recording over traditional digital video recording, I first began to decide how production would work for the show. *Hoosier Legends* had an extremely small production budget for each episode and a very short turn around time from filming, editing, and finally to airing the episode. The total budget for *Hoosier Legends* was $108,000 dollars that then divided into 36 episodes, which equaled $3,000 per episode. In comparison a show such as A&E's *Intervention* has a budget of $325,000 per episode. (Hamilton, 2010, p.1) The production team and myself would typically shoot everything the week prior to airing,

sometimes the week of, and then spend the following week to edit the half-hour documentary which would also stream to Fox Sports that Thursday. Fox would then air the first showing of the episode that following Monday at 5p.m EST. This process was ongoing for 36 episodes. Due to the tight budget and short time frame for filming I was forced to work with a small skeleton crew on each shoot, I however did not want to sacrifice aesthetic goals while filming the show. In comparison a recent production I worked on for ABC Nightline involved a crew of 6 members. The crew during the filming process of *Hoosier Legends* was made up of myself fulfilling multiple roles, such as a Director of Photography*, Camera Operator*, Gaffer* and Grip*, another crew member working as an audio technician and then one production assistant* doing various tasks. On other occasions the crew would be just the audio technician and myself. These challenges with production led to the decision to film the show utilizing RAW image recording on multiple RED cameras. This helped retain the ability to have the production values of a larger scale production with a larger budget and crew. The use of RAW image recording allowed myself and the crew to work in bad/mixed lighting conditions very quickly, where normally the lighting would have to be on a much larger scale and more finely tuned to achieve the same aesthetic values if a traditional compressed digital video camera had been used.

While RAW image recording in film production has taken a major step forward in recent years due to advancements in digital technology the notion of a RAW format is nothing new. Cameras were able to capture RAW information from a digital sensor after Eastman Kodak researcher Bryce Bayer invented the Bayer color filter array in 1976. (Bayer, 1976, p. 1) His RGGB Bayer filter* is used in almost every digital sensor now

that utilizes a square grid with 50% green, 25% red, and 25% blue.[1]  A RAW image is

sometimes referred to as a digital negative (DNG); it is the equivalent of a film negative,

an image before the developer has properly processed it.[2] The next step for a film

negative would be to process in a lab using chemicals, then have made into a print, which

is your final image.  In a way you can think of the chemical processing being done to a

film negative as the software processing being done to a RAW image before it is ready to

be shown.  The best part about film is that there was no compromise for it; there was no

compressed version of film like there is with digital imagery and videos.

 In photography and cinematography, camera sensors have substituted film as the

medium of choice.  While film was processed in a lab, digital is processed internally on

cameras and on computers.  This processing/compression though can degrade the quality

of the image that is first being captured from the camera.  However with RAW image

capturing the ability to process the footage at a later time, under a more powerful

machine such as a computer, has given the digital image advantages in quality and post-

processing options.  Through the show *Hoosier Legends* I was able to explore how RAW

motion picture imaging can shape the production and post-production workflow of non-

fiction video, as I was also completing a national level documentary that helped identify

the necessary steps to produce the content as efficiently and inexpensively as possible.

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[1] http://www.extremetech.com/extreme/99281-the-illustrious-history-of-kodak-inventor-of-the-snapshot-digital-cameras-oled-and-more/9

[2] http://graphicssoft.about.com/od/glossary/f/raw.html

# LITERATURE REVIEW

RAW image capturing technology is rapidly gaining traction in non-fiction video. Several other documentaries such as ESPN's 30 for 30 exclusive *Roll Tide/War Eagle* (2011)[3] or *Inside Job* (2010)[4] have both used RED digital cinema cameras that utilized a RAW image workflow for producing the documentary. In this section I do a technical review of the previous knowledge and history involved with RAW image capturing while also explaining how it correlated with the production of *Hoosier Legends*.

## Bayer Pattern

The Bayer Pattern was invented by Bryce Bayer of Eastman Kodak Company in 1975 and was later patented in 1976. (Bayer, 1976, p. 1) This invention relates to imaging devices and in particular color imaging devices and how they are captured. With the Bayer Pattern color imaging is provided by a single imaging array, this pattern alternates between a row of red and green filters with a row of blue and green filters. However, this array is not evenly divided, there are as much green filters as there are red and blue filters combined. The reason this method is done is because the human eye does not perceive colors equally, there needs to be more green filters to create an image that is closer to the true color the eye is perceiving. (2014, Digital, p. 1) Some of the advantages

## Analysis of Previous Projects

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[3] Roll Tide/War Eagle (2011) covers the venomous and consuming in-state college football rivalry that is Alabama-Auburn.

[4] Inside Job (2010) provides a comprehensive analysis of the global financial crisis of 2008.

that were brought about by the Bayer pattern are that only one sensor is needed and

sequentially all the color and luminance information can be captured at the same time.

(Bayer, 1976, p. 1)  This also allowed for cameras to be much smaller, less expensive and

more versatile.  The RAW image output coming from a sensor utilizing the Bayer pattern

filter is a mosaic of red, green, and blue pixels of different levels of intensity.  Once this

process has been recorded the digital camera uses a demosaicing* process to convert the

mosaic image into an image of true colors, what is important here is that each of the color

pixels can be used multiple times and the true color of a single pixel is determined by

averaging the values of the nearest surrounding pixels (Bayer, 1976, p.1).  This Bayer

pattern is the same filter array used on the RED Epic camera, the same camera that was

used to record the *Hoosier Legends* show. There have been attempts at alternative

approaches on filter arrays for capturing light such as the Striped RGB*, Three-Chip

RGB and Prism*, and a Stacked RGB* filter array (Appendix B, Image 1). As

RED.com's site details, the optimal strategy is that of the Bayer filter array that takes the

most advantage of each photosite available from the sensor. (2014, Bayer, p.1) The Bayer

Filter enables the sensor to take full advantage of the available light and information first

provided to the sensor.

**Color Space**

Color Space (Appendix B, Image 3) is way of defining the value range of colors

that a device such as a camera, printer, or monitor is able to reproduce.  Color Space is

however not to be confused with a Color Model*.  There are two forms of color models,

one being additive, such as RGB* (Appendix B, Image 4).  The other form of color

model is subtractive, for example CMYK* (Appendix B, Image 5). Color Space is the

type and number of colors that originate from the combinations of color components

of a color model. (2014, Color Space, p.1)

Each color space allows for different levels of color to be reproduced, some of

the color profiles are much more limiting than others and the range of colors able to be

reproduced is thus limited. This gives the viewer and editor of the image much less

colors to see and work with when manipulating the image but by defining the color space

the user is using it will be accurately reproduced on other devices. On the other hand, if

the color space the editor worked in was different than that of which the final image is

viewed on it will not retain the same look that they had originally edited the image on

(Color Spaces, 2003, p.1). The reason this is important to the show *Hoosier Legends* is

that I was working with a RED Cinema camera that recorded in a RAW format that

would let me choose between multiple color spaces when editing the image in post-

production. However since the show would air on broadcast or cable high definition

television when completed, the color space was already defined, so I had to edit the show

from within those parameters which are the rec. 709 color space (Appendix B, Image 3)

or more properly referred to as ITU-R Recommendation BT.709. This is the

international television standard for color space that ensures the playback of every

television should match what the television show was edited in (Log C, 2014, p.1). The

choice of rec. 709 color space being the standard for television means that any footage

aired on television must be within this same color space to be shown.

**Gamma**

The next terminology that is used with RAW imagery is "gamma". Gamma is

defined as a term used for referring to the tonal characteristics of an image. Gamma is

the middle range of a gray scale chart that ranges from complete black to complete white, detailing the tonal range* of an image. However, the gamma can be manipulated from its initial point to the change tonal values of the image being displayed or recorded. For example, the interview with Bobby Leonard originally had an over abundance of details in the shadows* and a lack of detail in the highlights* and mid-tones* of the image for my personal liking. By repositioning the gamma level with the image I was able to shift more information from the shadows into mid-tones and highlights, thus giving the image a more pleasing look in this particular instance. Changing the value of the camera and shifting the gamma upwards towards the white values helps stretch out the tonal range of the highlights of the picture but compresses the shadows (black) values of the image. In contrast, shifting the gamma point towards the black values gives shadows additional values and more gradations while compressing the highlight range of the image. The overall effect of shifting the gamma is to change the contrast of the image to how the user likes. (Beacham, 1994, p.36) This relates to the sections in *Hoosier Legends* where I discuss gamma curve settings available with the RAW footage being recorded. Through out the *Hoosier Legends* post-processing of footage there were situations where the gamma level of the image would need adjusted to create a more proper tonal range throughout the given image.

**Data Compression**

Data compression for video is the process of finding patterns, using complex algorithms in the data and rewriting to minimize the bit rate*, rate at which data is transferred, of the original source of information, and/or to reduce the total file size. There are many advantages to compression, some being the ability to stream an image

source that may have been to large or high of a bit rate to be played back on other devices due to their lack of bandwidth or processor power.  Lowering the bitrate of these images allows the image to be viewed on more devices that did not have that power to process the uncompressed source.  Another way of lowering the bitrate is by lowering the frame rate* of the camera recording the image, but for Hoosier Legends I decided to record the show at 29.976 frames per second.  Additionally compressing an image allows the user to change the format of the media into a possibly more widely accepted format from its potential proprietary one it may have been in originally.  For example, with still images taken on a Nikon DSLR utilizing the RAW technology of the camera, the file is stored in a proprietary format from Nikon that can be opened on few devices. After compressing the image to a format such .jpeg the image can now be viewed on multiple platforms and devices.  (Bhaskaran, 1997, p. 1) This relates to the production of *Hoosier Legends* when I am discussing the different levels of compression that take place when recording video and when working with RED RAW imagery from RED cinema cameras.

**RAW converter**

The next element of working with RAW imagery is the notion that the file needs to go through two stages of processing.  The first step in this process is to access the RAW file in a program that specifically works with RAW imagery before going into the second level of editing, for example a non-linear editing program for video.  RAW converting and editing is the process that RAW imagery goes under when a RAW file is opened in a RAW converter or editing program on a computer.  Photoshop first introduced their RAW converter software as a plug-in inside of Photoshop 7 that was released in 2002. (Fraser, 2004, p.1)  This plug-in is now available in Photoshop and

Photoshop Elements, this plug-in can access various proprietary RAW formats from cameras, due to each camera brand having their own unique variant of the RAW format attained from the sensor. The RAW converter allows the access of all the beneficial features RAW possesses, such as adjusting gamma curve presets, picture style presets, color space, white balance, magenta-green tint correction and various adjustments to get proper exposure. (Fraser, 2004, p.1) The reason this relates to *Hoosier Legends* is that the show was shot on cameras that utilized RAW technology that was then processed in a RAW converter program inside of Premiere Pro, a non-linear video editing program.

**Communications Protocol**

The production and post-production process of *Hoosier Legends* was greatly benefited by the file transfer speeds of technology that were available at the time of the production. Without this most recent boost in the speeds of various communication protocols*, the production of the documentary would have to work at a much slower speed and in therefore would have to make sacrifices from the show. During production for *Hoosier Legends* the team utilized USB 3.0* and Thunderbolt* connections to transfer the data from media devices, that were used to record the show, to a storage device to edit the show off of. The storage device used to edit the show from was a hard disk drive* that was using a Thunderbolt connection as its form of communication protocol. USB 3.0 and Thunderbolt were both relatively new at the time Hoosier Legends was being produced. Without their benefit in speed of data transfer, production team would not have had a timely completion. USB 3.0 is the third generation of the USB interface, introduced in late 2008. This newest update to the USB connection

device increased the speed of data transfer from 480 Mbps[5] to 4.8 Gbps[6] a 10x increase

from the previous version of USB, USB 2.0. (2014, USB 3.0, p. 1)  Apple computers, on

the other hand, first introduced thunderbolt, on February 21, 2011 in their newest

MacBook Pro. (2011, Thunderbolt, p.1)  Thunderbolt's connector was able to give users

10 Gbps throughput in both directions that the data was being transferred.  This device

was twice as fast as USB 3.0. Other additional features that Thunderbolt provided were

the ability to connect a display port from the connection port and it's ability to daisy

chain* multiple high speed devices.  An example of where this was a benefit on the

*Hoosier Legends* production was when I was filming the Bobby Leonard interview and

also his wife's interview at his house, away from our production office.  During the

filming of the interview I was able to exchange media cards from the camera with the

production assistant who was transferring the data from the cards to a hard drive while on

set.  Each media card I was using with the RED Epic camera was 128 gigabytes and I

was filming on two cameras simultaneously.  The amount of time the interview took to

record was over the limit of time I had available on the media cards provided.  Utilizing a

USB 3.0 media card reader and a laptop with USB 3.0 and Thunderbolt connections I

was able to offload the media from the cards to two separate hard drives that were daisy-

chained together.  This technological ability gave the production the adequate transfer

speeds to properly store the footage filmed onto two separate hard drives and then be able

to re-format the media card so it could be used to continuously record the show.  Without

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[5] **Mbps**, short for megabits per second, a measure of data transfer speed (a megabit is equal to one million bits).

[6] **Gbps** stands for billions of bits per second and is a measure of bandwidth on a digital data transmission medium such as optical fiber.

this advancement in data transfer speeds, the show would have been halted when the capacity of the media cards available was reached and the production team would be waiting on the footage to be properly stored before being able to continue production.

**Demosaicing**

While the Bayer filter array is an outstanding device for gathering light and color information to a sensor, it isn't final stage in attaining a correct image when utilizing this filter array. The next step that needs to be done, after the information is gathered from the sensor, is that the information needs to go through a process of demosaicing also referred to as debayering.

The Bayer array as identified earlier, captures light and color information from three different color photosites. These three photosites are red, green and blue however these photosites are not evenly distributed across the filter. There are as many green photosites as there are red and blue combined. The reason this is done is because the human eye does not perceive colors equally; green light is more sensitive to the human eye than either red or blue. By having more green, than red and blue photosites, the sensor is more sensitive to light. With the sensor more sensitive to light the image appears less noisy than if they were balanced equally. This can also be attributed to why noise is more prevalent in the red and blue colors than it is in green.

The image that is captured using the Bayer filter array is not a complete image; it is a mosaic of these red, green and blue photosites taking up each pixel in the image (Appendix B, Image 7). The next step is to now demosaic this image. This process involves translating the mosaic of red, green and blue colors into a final image that

contains full color information at every pixel (Appendix B, Image 8). This translation is referred to as interpolation. There are various forms of interpolating the mosaic image into a final image. Some of the interpolations listed are Bilinear*, Nearest Neighbor*, Smooth Hue* and Edge-Sensing Bilinear*. Each of these interpolations chooses a different way of determining what final color will remain in the pixel to create a full image.

The RAW footage recorded by the cameras I was using allowed this demosaicing process to be done on a computer once the footage was properly brought into a RAW converter. While other cameras that don't store RAW information to the media card, process this information internally in the camera. The ability to demosaic the image on more powerful machine renders better results for the image by using more powerful processors. This also future proofs the RED footage for improvements that may come in the future with different demosaicing algorithms in contrast to being limited to the only algorithms available at the time the footage was recorded. (2014, Redcode, p.1)

**METHODOLOGY**

Production for *Hoosier Legends* began in September 2013, the first episode was on Bobby "Slick" Leonard, former NBA player and coach of the Indiana Pacers. The production team and I had one week to film the primary interview with Mr. Leonard, supplemental interviews of people who could discuss Bobby's career, stand-up pieces with our host Brian Hammons, film b-roll of Bobby at his job and b-roll of old photos of him throughout his life. This was a large amount of production to take place in one week and especially for how small my crew was for the show.

This being the first episode for *Hoosier Legends*, it was necessary to formulate a shooting style that would stay consistent throughout the rest of the season. There was a lot of footage to be filmed for each episode and time requirements were extremely short. Going into production, I knew that I wanted to utilize RAW camera technology during the filming process to help with the tough conditions the show would face and to maintain the highest possible level of quality that could be produced in regards to the camera technology alone. For the primary interview with Bobby Leonard, I needed two cameras – one for a medium shot and another for a close up shot*, on our main subject and one reverse angle for the host, Brian Hammons. The two most important cameras in this specific setup were those filming Bobby Leonard, while the reverse angle with Brian was used very sparsely during the show. I had two RED cinema cameras and a DSLR* (Digital Single Lens Reflex) camera available for each primary interview. I decided to use the two RED cameras that were utilizing RAW video format for the close up and medium shots of Bobby. For the reverse shot of the host, I alternated between a Canon 5D mark ii and Nikon D800 DSLR camera. It would have been ideal to have three RED

cameras to cover every angle, but the show's budget was not able to cover a third RED

camera angle.  I did my best to match the DSLR camera's "look" to that of the RED

camera I was using by fine tuning the settings on the camera's picture style to match the

native RED footage. I was not as worried about not having a RAW video format for the

reversal due to that camera angle's lack of actual airtime on the show.

**Production**

The very first interview was to be conducted at Bobby Leonard's house and we

had also planned to do a supplemental interview as well with his wife after we had filmed

with Mr. Leonard.  When the crew and I arrived at Bobby's house we had one hour to do

our first setup up with Bobby and Brian.  It was a relatively warm day outside and I liked

the look of his front porch in comparison to possibly filming a three-camera angle

interview inside his house.  One problem that arises with a three-camera angle interview

is that you need to light for two subjects and also set up the look of the shot in two

multiple directions.  Shooting on Bobby's porch gave us the ability to have the room to

shoot multiple directions with both Bobby and Brian on the porch talking to one another.

The lights available for us to use were Kino Flos* and 2000 watt Tungsten* lights.  I

prefer to always use Kino Flos during documentary filmmaking because they can easily

switch from daylight to tungsten, they have a high color-rendering index*, and they are

powerful large lights.  I decided to use three Kino Flos on Bobby, two for my key light*

and one for my hair light*.  We needed two key lights on our interview to balance out the

exposure with how bright it was outside.  This is one aspect where the RAW image

technology from the RED cameras plays a vital role in the production process. The

lighting conditions were constantly changing during the long interview between Bobby

and Brian and utilizing RAW technology I would then be able to tweak the image in post production to a greater degree than a compressed signal, which would not hold up as well with major corrections in post. I knew while filming that I would be able to recover more highlights and shadows in the image from the RAW format of filming. In an ideal situation for lighting I would have had more powerful lights that would help properly light our subject. This however was not possible with the budget for the show, so the ability to shoot in RAW on the RED camera's helped circumvent this problem. The RAW image from the RED sensor also gave me the ability to retroactively change the white balance during different time increments of the shoot, since RAW has no baked in white balance you are able to fully manipulate it when you process the files on a computer. The need for this was due to the white balance* constantly changing as the sun set and clouds would pass over shifting the white balance and color temperature back and forth on the Kelvin scale* (Appendix B, Image 6) and on my camera. Another area that RAW was helping on this production was that each RED camera had a different lens manufacturer on it. One RED Epic utilized a Canon lens, while the other RED Epic had Nikon lens. RAW was helpful in this regard because each lens has a different color it perceives stronger, with some lenses running warmer while others run cooler, this means that some have more of a blue tint to them and others have a more red-orange color to the lens. I could help tweak this more properly in post so that the two cameras would match and you would not notice a large difference between the two. With a non-RAW camera you would be able to discern the color tint difference between the two cameras more easily, and in non-fiction documentary filmmaking there is not always a high enough budget or the availability to have perfectly matching lens for each camera being used.

After I finished filming Bobby's interview, I then setup the 2$^{nd}$ interview to film his wife also on the porch but at a different angle. This interview would be the first supplemental interview filmed for the show. For this interview we filmed with the two RED cameras since we did not need to film Brian's angle and we were able to choose an easier location to film her interview and light for only one person. Further in the show I decided to only use one camera for the supplemental interviews to help with the amount of data being used and to help speed up the process of editing the show. Once finished filming the interview with Bobby's wife, I wanted to shoot b-roll of her at their house walking around to help intercut with the edit of the show. With RED camera's high dynamic range and ability with the RAW technology to capture the highest detail and color information possible coming from the sensor while using proper compression schemes, I was able to not worry about "compression artifacting*" of the image. This type of artifacting stems from a lossy compression* used to process the image that can sometimes cause noticeable distortion. I shot her walking around in the natural low light the house had inside of it. Normally in such low light conditions, noise and compression artifacts of the image can be an issue from shadow details not retaining all the information being recorded. This is due to compression schemes choosing to lose information in certain areas of the image and try to retain it in other areas. The RAW image capabilities made me not worry about this problem when filming her in these lighting conditions.

From this point it was time to find and film supplemental interviews to help build the story on Bobby Leonard. The first supplemental interview was with *Indianapolis Star* sports writer, Bill Benner. The interview was done inside of a library with more

mixed lighting conditions. A combination of compact fluorescent bulbs, tungsten lights and daylight coming in from the windows made the room full of multiple kelvin temperatures and hard place to get a correct color balance. With the Kino Flo lights that were used for production the team was able to mix the bulbs on the light system to make it half daylight and half tungsten. This is a good technique when you are in mixed lighting conditions and do not have the ability to change everything in one room to the correct, consistent color balance throughout the image recorded. So in return you mix the lights that you are using to light your subject so they are mixed as well. You then split the difference on the kelvin temperature you choose for your camera. For example, a normal daylight condition would be anywhere from 5200-5800 kelvin. A normal tungsten lighting condition would be anywhere from 3100-3600. When you "salt and pepper" the lights you use the kelvin temperature would be anywhere from 4200-4800 kelvin temperature. Something I learned on an earlier film set I worked on with a well-established director of photography.

The second supplemental interview was done in the same library just set at a different angle from the previous interview; this interview would be with another *Indianapolis Star* sports writer, Robin Miller. An issue we ran into here on this particular setup was the brightness level of the desk lamps in the library behind our subject. These could have been framed out but it created a nice image with them in the background and gave our hair light on the subject justification and a sense of it being naturally lit in contrast to it looking very obviously lit. In a normal situation with more time to change things I would have dimmed the desk lamps to a proper exposure to match what we needed. But with RED cameras we were using they maintained a high level of dynamic

range that was benefited by the fact the camera was recording in a RAW image format that retained more of the original image and allowed there to be more details in the highlight and shadow range. This was also heavily benefited in post production when I was able to recover more of the highlights in the original image, this technique would be virtually impossible unless recorded in RAW video format where you are able to recover highlight details and also able to change the ISO in post production.

The third supplemental interview for the *Hoosier Legends* episode on Bobby Leonard was with former Indiana Pacers player, George McGinnis. This interview was easy for the production team because it had been previously recorded and we were able to use the footage in our documentary. The footage was recorded on a Sony F5 camera that was recorded in a non-RAW format, the footage has a distinct look to it and is different than our look for the show but not so different that it would not intercut well with our footage. The footage from when I preview it has a distinct green cast to it, that I believe could have been easily adjusted for in post-production if recorded in a RAW format where I would easily be able to adjust for the tint in the magenta-green cast that is usually attributed with LED lights and fluorescent lights. Setting up another interview with George to record on our specific cameras was not possible so we defaulted to the footage available for us, which ended up saving us money and time on the show.

The next step in the *Hoosier Legends* production style was to record "stand ups" with our host Brian Hammons. Stand ups involved Brian doing three to four different scripted lines speaking straight towards the camera, or audience. For this episode I thought it would be a good idea to film the stand ups in Bankers Life Fieldhouse, home of the Pacers and a place that represented Bobby Leonard well. This area would however

pose a problem with lighting again due to the lighting being sodium vapor lights. These lights cast an unusual kelvin temperature at a level below that of normal tungsten lights and were also inconsistent from light to light. High-pressure sodium lights run at a color temperature of 2700 kelvin while the normal tungsten lighting is equated at 3200 kelvin[7]. The Kino Flo lights I was using had a choice of 3200 kelvin bulbs or 5600 kelvin bulbs. The closest I was able to get was to go 3200 kelvin on the bulbs and split the difference between the two color temperatures in post production, another opportunity to fine tune white balance again with RAW technology in post production. The lights also casted a green tint which we had to correct for as well with the tint slider setting in the RAW editing program inside the non-linear video editing program we were using, Adobe Premiere Pro CS6[8]. Some of the stand ups with Brian were done using a camera slider with him walking while others were done with him sitting in the stands talking to the camera. I thought shooting in Bankers Life Fieldhouse really helped establish the show due to the first shot of the show being Brian's introduction to the episode and the show itself.

After filming with the host of *Hoosier Legends,* Brian Hammons, the next step was to film b-roll footage of Bobby at his current job. This would be referred to as a day in the life style of filming. Following him around at his job and getting aesthetically pleasing shots in slow motion of him working and the energy of one of the Pacers game at Bankers Life Fieldhouse where he works as one of the correspondents discussing the game. This filming process matched the same style we were doing with Brian Hammons

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[7] http://www.venturelighting.com/techcenter/lamps/color_of_light.htm

[8] **Adobe Premiere Pro CS6** software is the industry-leading cross-platform video editing software. Edit low-resolution to 5K and higher resolution footage with greater speed and precision without transcoding.

stand ups, and under the same lighting conditions but this time we only used the sodium vapor lights provided in the building and did not bring our own lights for the shoot. This let us better fine-tune the kelvin temperature and color balance since now the lighting was more consistent throughout the image recorded.

The last and final stage of the filming process for the show was to film "b-roll" footage to help support Bobby's story throughout the episode, this was the supplemental or alternative footage intercut with the interviews of the documentary. Bobby thankfully had a large amount of well photographed images of himself throughout his basketball career that I was able to creatively film for the episode. There were two methods to getting these images on video. One method would be to scan in the images given to us on a scanner and have digital pictures files for us to then manipulate in the video editing program. The second method, and the one I found more aesthetically pleasing, was to figure out a way of filming these photos in various ways and set ups to make something more creative and more enjoyable for the viewer to watch. Going through Bobby's photos, I categorized his photos by different points in his career. Most of photos were large printed glossy photos that reflected light well, and others were film negative slides he had from when he was younger along with newspaper clippings and books about his life. All the photos of Bobby were old black and white photographs from when he was younger. I came up with the idea to film a large amount of photos at once due to the lack of time to film each photo individually. I created three lines of photos separated by a few feet each between each section, such as if you were hanging clothes on a clothesline. The photos were then hung on fishing wire and had tape holding them to the back of each photograph to suspend them in the air. This to me helped bring each photo back to life

and created more of story with the ability to see each photo of his life in a wide shot and then being able to zoom in on individual photos while moving the camera from left to right on a small track which allowed for lateral camera movement. This technique of filming helped breath life back into these old photographs and gave the show a unique feel.  I filmed this portion of the b-roll in a large open building with older vintage windows allowing daylight to come in and help fill the area.  The way I lit the photographs was with a large 2000-watt Mole Richardson tungsten light and a soft Kino Flo source with 3200-kelvin bulbs position behind the camera as a key light.  The 2K-tungsten light acted as a hair light that helped give the photographs a three-dimensional feel of separation.  I also chose to position this light on an old Mole Richardson rolling stand and leave the light physically in the shot, a technique usually frowned upon to leave lights in the shot.  I did it as an aesthetic choice and help put some history and authenticity to the photographs.  This idea worked because Mole Richardson lights were first invented in 1927 and have been a standard in Hollywood film sets for years to come. (2013, Company, p.1) The specific 2K Fresnel* tungsten light I was using in the shot is over 50 years old and helped put the audience back in a time when these photographs may have been taken.  For the key light, which was positioned out of the shot, I used a Kino Flo. Kino Flos are still relatively new lights that would not have fit that time period and would be awkward in the shot.  In regards to the camera settings and kelvin temperature, the daylight coming in from the windows was close to 6500 kelvin due to an overcast day and the tungsten and Kino Flo lights were 3200 kelvin, complete opposites on the color temperature scale.  I could have corrected this by switching the bulbs of the Kino Flo and putting a CTB (color temperature blue) gel over the 2K Fresnel light to

bring the kelvin temperature to 5600 kelvin, a much closer color temperature to that of the window light pouring in. I decided however to stick with 3200 kelvin from my light source to give the photographs a more warm feel and the background a more dark blue grunge feel to help bring emphasis to the photographs being filmed. With the RAW abilities in post production I was able to heighten this feeling more and refine the color of the image to help lower the saturation of the blue and balance between the tungsten and daylight coming in better to help accomplish the feeling I wanted to give off with the image. Where RAW imagery really benefits a director of photography, editor or director in this situation is the ability to completely change color temperature of the image inside post-production if they decide to give the image a different look later on. It helps give the person color grading the image the ability to make major adjustments without any degradation to the final image. With a compressed non-RAW source image you would not be able to accomplish this color grading and correction on such a large scale or nearly as fast.

The next b-roll filming was of pictures falling in slow motion and of scrapbooks flipping he had made for him over the years, this set up was simple and only used a Kino Flo to light the pictures. The last piece of filming was of the negative slides that Bobby had. These I decided to light using a light board that would illuminate the photographs from underneath. Then in postproduction I would flip the image with a negative flip that would properly turn the negative image into a positive image and would give the image the feel of a processed photo in contrast to just looking at a negative image. This color balance of the board was somewhere around 5600-kelvin but the color temperature was not as a big a factor due to the fact we changed it to black and white in post-production.

The ability to choose different ISO's in the RAW editing program in post production was a benefit here in properly getting a correct exposure on the image that was hard to monitor at first because we were filming a negative that would then be later changed to a positive image.  The RAW ability to hold more details in the image benefitted this post production process by not degrading the image when the image flipped, where normally details in the highlights and shadows might not have handled such a drastic change in a non-RAW image where certain information is thrown out to step the image down to a compressed image.

**Post-Production**

The filming process was now complete and it was time to begin the editing of *Hoosier Legends*.  The footage for this show had been logged on two separate hard drives and stored on the production team's server to guarantee it was now safe and could not be lost.  Brian Hammons and the editor of *Hoosier Legends* worked on editing the show together in the few days we had to finish the project before sending it off to Fox Sports Midwest.  Once the show was completely edited it was my turn to begin color grading* and refining the image of the show.  The first step I began with was color grade and matching the look of the three-camera interview of Bobby Leonard and Brian Hammons. The program I was utilizing to edit the show was Adobe Premiere Pro CS6, this is a non-linear video editing program that allows the usage of RAW video shot on the RED cinema cameras to be edited natively on the computer without converting the RAW material into another format.  This process is often referred to as 'transcoding' and was a step I sought to avoid.  The nice part here and something that was not available until recently was the ability to edit RAW video footage natively on non-linear video editing

program from Adobe, previous versions of Premiere Pro were just beginning to allow the use of RAW video to edit from but it was still very processor and software intensive to do so. Now with Adobe's CS6 system and the their most recent Creative Cloud system, editing RED footage natively is done so very easily. To begin the initial color grade I would access the footage inside the bin that holds all the footage in Premiere Pro, from here I would open up the footage in another program within Premiere Pro titled "source settings" inside this program I was able to harness all the abilities shooting in RAW video provided when going about color grading. The source settings program inside Premiere Pro is very similar to the Camera Raw editing program you see inside of Adobe Photoshop, another program that processes RAW imagery. My background in photography helped me better understand the settings available for me to use within this program since I had been working with RAW imagery in still photographs for years now, a program that is relatively easy to grasp an understanding of. These programs give the editor complete control of the image to manipulate when working with RAW imagery, these programs however do not let you edit non-RAW video or stills since they do not possess these abilities to post process the image. What is happening here is that these RAW processing programs take away the processing functions that the camera does when an image is taken, processed internally, and stored to a compressed non-RAW format. Those functions being white balance, gamma curve, color space, ISO, demosaic algorithm, sharpness, exposure levels and tint correction. Instead you retain all the information that is recorded from the camera, store it in a RAW format, then take it into a program and selectively do the processing of the image yourself. This gives the user much more control over the final image in comparison to having an image that has

already been processed and lacks ability to be processed off the original sensor information in an editing program. The first thing to do with Bobby Leonard interview was to begin matching the two RED cameras color together, this process was made easy for me with the source settings program. I began first by editing the A camera angle from one of the RED Epic cameras. This was the wider of the two shots and displayed more area for me to see, I always try to edit from the wider of the two shots first then copy over the settings to the closer camera angle. The first step you must do with RAW footage from the RED cinema cameras, inside of the source settings program in Premiere Pro, is to choose your color space and gamma curve. When I was deciding the color space to work inside of I had to determine where the final footage would be displayed at, there are many different color spaces and various standards chosen for proper viewing on devices. *Hoosier Legends* would air on HD television, the color space for this type of device and playback was rec. 709 color space or more properly called ITU-R Recommendation BT. 709. This color space is more limiting than what the RAW image can record at other various color spaces, but has been a standard now for many years with television viewing. The ability to choose multiple color space settings is a great advantage that recording in RAW imagery allows. Other digital cinema cameras that are not utilizing the RAW technology, such as an Arri Alexa camera setup when not using an external recorder, only allow one option of color space to be chosen. When recording with Arri Alexa you can choose from rec. 709 or Log-C* as a color space to record at, both of these color spaces are recorded to a non-RAW video. The rec. 709 color space when recorded is a very limiting image in terms of dynamic range and color, while the Log-C is a much broader color space that gives the video image more information to then work off of when color

grading in post production, but is still a compressed non-RAW image as well and lacks the advantages of color grading that RAW possesses. On some productions the ability to see everything being recorded in rec. 709, then go straight to edit from that image recorded and knowing exactly what you are seeing on the shoot is what you will have as your final image can be an advantage. However if you plan to do any color correction or post image processing it will degrade the image due to lack of extra information not being recorded in rec. 709 color space. This to me is why recording in a RAW video format is again a great advantage to have available, especially in non-fiction documentary filmmaking where there is not always all the tools and time you have available to get the image exactly how you want it on camera without any post processing. Also this gives the editor the ability to re-master the color in various color spaces if it will be displayed on various displays other than high definition television.

So the next step after defining color space was to choose my gamma curve inside of the source settings program, here again is another area where RAW helps provide something that wasn't previously available with non-RAW video. Inside of the source settings program there are 5 Gamma spaces available to choose from, REDgamma, REDgamma2, REDgamma3, REDlog and REDlog film. REDgamma 3 was not available until recently, before this there were only 4 gamma curve choices. The RED company has released new gamma curve choices over the years and I believe they will keep putting out new gamma curve settings as time continues. This helps breath new life into new and old footage each time by giving the editor more options to choose from when they are defining the look of the final image. Gamma curves can however be applied to non-RAW video as well but they are working off an already compressed image, not the

camera's original sensor information which this may lead to degradation of the image, this is why cameras such as the ARRI Alexa allow two choices, one being Log-C and the other rec. 709. The Log-C settings help give a flat image, that looks very desaturated and lacks contrast in the image, they are trying to preserve every bit of information they can retain in the compressed image recorded. However with RAW none of this is actually done on camera, you can always go back into the editing program on the computer and choose various color spaces that are still working off the original sensor information provided from the camera, this ensures that any gamma curve is not working off an already compressed source and is still the first and only gamma curve settings applied. In non-fiction documentary filmmaking the production team might not always have the time to get the image perfected exactly how they might like it to be. But with this ability in post-production they are able to refine the image to a more pleasing or stylized image that might better fit the style of the documentary. This is the same thing photographers will do inside of Camera Raw settings on Photoshop, they have multiple "picture styles" to choose from when editing if they chose to shoot in RAW, if they didn't shoot in a RAW format they would be limited to the gamma curve (picture style) settings they chose inside the camera that they are now unable to change in the post process editing program on a computer. For the episode on Bobby Leonard I utilized the REDgamma 3 settings, I liked the contrast and way it handled the shadow details of the image.

After establishing my gamma curve the next settings to establish were the white balance, tint, ISO*, shadows, exposure, saturation and contrast of the image. Working RAW imagery you are able to re select the white balance in post production and change the tint, the same way you would be able to do so when taking the original image on the

camera. This is a major difference between a RAW image workflow in comparison to a non-RAW workflow. Without shooting in RAW the image is hard locked into whatever white balance and possible magenta-green tint correction the photographer decides to choose. Having the ability to change your white balance in post-production is a huge advantage, giving the editor room to make corrections or change the tone of the image drastically by changing the kelvin scale of the image. This allows an image that may have been properly white balanced to the proper Kelvin scale on the day of the shoot to now be properly refined with no degradation to the image due to it still using the original information recorded from the sensor, no in camera processing. Another advantage shooting on a RED Cinema camera with RAW imagery technology provides is the ability to choose the ISO range of the image in post-production, this option is again not available in a compressed non-RAW source. The RED Epic camera has a base ISO of 800, this means that the image at its highest quality and dynamic range is recorded at 800 natively. However, you are still able to select multiple ISO settings on the RED to help better your exposure and dynamic range in shadows or highlights. A great asset of the RED shooting at a base ISO of 800 and having the ability to reselect ISO in post production, is when I would be shooting at an outside location and the exposure of the image would not be exactly perfect and could be slightly overexposed, I could then take the image in post production and lower the ISO from its base 800 to an ISO range of 640 or even lower. This would give back my image the highlights that may have been clipped in the image while recording. Another technique available is when shooting in a darker location with more shadow detail I could shoot at an ISO of 320 and then in post production if I needed to I could bring the ISO setting back up at different increments. When recording in a

non-RAW image format the photographer is locked into whatever ISO range they choose during the shoot.  So if for some reason the highlights or shadows are clipped there is very little an editor can do to save this information.  On a production with a more time and more lighting options to get proper exposure and settings this would be a minimal problem, but with non-fiction documentary filmmaking there is not always time for this proper camera settings if you are in tough locations that have varying exposures in the image.  After ISO range had been selected I was then able to properly choose saturation levels, contrast and shadow details of the image.  Working in the source settings program I was manipulating the image from the original sensor information recorded, in comparison a compressed non-RAW source image I would have been manipulating the color based off the compressed pre-processed image recorded.  This way of editing can easily lead to image degradation if the image was to heavily color corrected while the RAW image would not suffer under these same major corrections in color.

**Delivery**

These abilities to control the image allowed me to make major corrections with the image in tougher filming conditions with little time for setup or pre production, I was able to balance the image between the three cameras, choose proper exposure, fix magenta-green tint corrections from bad light sources and manipulate my white balance, gamma curve, saturation and shadow details without any degradation to my final image. At this point it was time to send the episode to FOX Sports Midwest.  After exporting the show I would then send a hard drive with the completed episode to FOX Sports, who would then offload the show and then it air that following Monday at 5pm Eastern Standard Time.  Once the show had successfully aired the production team would store

the entirety of the show, all the footage, audio, graphics, project files and still images recorded to a tape device system. This tape device system had a much longer shelf life than that of hard drive. This now means the first episode of *Hoosier Legends* had officially been completed and archived safely for possible future use. Following the completion of the first episode would begin the next 35 episodes of the show for *Hoosier Legends*, with each production bringing new challenges to the production that the ability to work in a RAW image format would help benefit the production team again and again.

To help summarize the process the RAW images captured for *Hoosier Legends* went under, the first set was properly capturing the imagery on both RED Epic cameras. From here the footage was brought into a RAW converter that then processed the image into footage that could then be edited in a non-linear video editing program. Once the show was complete it would then be exported to a final video, stored on a hard drive and sent to Fox Sports. After the show had successfully aired on television, the production team would take the entirety of the project used to make that specific episode and store it on a tape device, once this final step was complete that particular episode of *Hoosier Legends* was done.

**DISCUSSION**

After the first episode of *Hoosier Legends* on Bobby "Slick" Leonard was complete I was able to see what worked and what didn't work and then take this knowledge to future episodes of the show. I also was able to step back and see the advantages and disadvantages that the RAW video workflow provided the opening episode of *Hoosier Legends*.

The first thing I immediately discovered when working in a RAW video workflow is the amount of data that it took up when filming long interviews. This could be a disadvantage to many productions because the more data you record the more space needed to provide proper storage. This led to the production team having to buy multiple hard drives to create the show, which would be unnecessary using a non-RAW video workflow. Commercial production might not see this so much as an issue but a non-fiction documentary style of filmmaking where long takes are often a necessity and the budget of production is not as high, I could foresee this being an issue. Lucky for us we were able to still film in RAW and had the budget for hard drives, requiring us to be more cost-efficient on the hard drives we acquired. Another issue that sometimes arose on the set of *Hoosier Legends* when dealing with data was the amount of media cards we had available for each camera to record on. Each RED Epic camera on *Hoosier Legends* had three 128GB solid-state drives*, or SSD cards. Each card only recorded roughly around 38 minutes of footage, which would allow the production team roughly 1 ½ hours for interval of filming before the footage needed to be properly offloaded onto a hard drive. This however was a problem on a few of the productions where there was more time needed to record than this 1 ½ hours provided. I had three options available now at this

point to circumvent this problem. The first was to buy more SSD cards for each camera but at a price of $1250.00 per card this was out of the question. The 2nd choice was now to increase the compression and to lower the data size and bit rate recorded. I did not want to go with this option and sacrifice quality of the image for the show. The 3rd option and the only I ultimately decided was best, was to utilize a "data wrangler" on the day of production. The production team would dedicate one person to the job of offloading the footage from the cards to a hard drive. (Wheeler, 2009, p.46) This would allow myself to constantly be filming while cycling cards between the data wrangler and myself so there would never be a time where I would have to stop the production and wait for more cards to be available.

Another potential problem for some productions is the power it takes from a computer to process RED RAW footage. This was not an issue for the *Hoosier Legends* production team who were utilizing computers with quadcore processors[9] and higher end graphics cards. But on a smaller non-fiction documentary film production, where the computers might not be as powerful, this could be an issue when trying to playback the footage during editing or exporting video. It would result in the production having to buy more powerful computers or work at a much slower rate than they possibly would have with already compressed footage that wasn't recorded in a RAW video format.

Some of the things that I hypothesized before production and in turn, helped the production, were the ability to match cameras with different lenses and of different formats by using the RAW cameras extra color grading abilities to properly match the

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[9]A quad-core CPU has four processing cores in a single chip.

cameras. I was not exactly sure before production how well I would be able to match the two cameras to get an exact look due to one camera using Canon lenses and the other using Nikon lenses. I knew early on that the different brands of lenses resulted in subtle color differences between the two, however I did not want the viewer to be able to notice this when the show aired. The extensive color grading options allowed by the RAW format helped me match these cameras even further.

Another area I had early hypothesized was that filming in RAW would help benefit various tough lighting conditions and that ended up being true when in post production there had to be corrections made to the kelvin scale of the white balance and magenta-green tined areas needed correction due to poor quality color rendering lights at some locations. Also the RAW ability to change ISO and recover highlights well benefited me when I was color grading the show and some areas were either to dark or to bright, something I would not have been able to adjust as well for without that RAW workflow that I utilized for the show.

One large problem I ran into when shooting in RAW video or still photographs compared to a lossy compressed video or stills, such as .h264 and .jpg, is that RAW imagery takes up a large amount of data. Due to all the information being stored in a RAW image it will add up to a large amount of data per minute of recording. There were various ways for us to counteract this problem though, and with the RED cameras I was using, had the ability to choose compression ratios that would help limit the size of the files being recorded per each minute of recording. Doing this however would sacrifice some quality of the footage, which I also did not want to do. I had to test out different compression ratios to find what best worked for quality and also for the amount of data

being recorded. I eventually settled on a 10:1 compression at 5K resolution for each

camera, the camera varies from 3:1 compression all the way up to 18:1. This

compression, which is also referred to as Redcode[10], let us record approximately 38

minutes on each 128 gigabyte card. Most of our primary interviews would run for

slightly over 1 hour of filming which would end up in around 512 gigabytes of footage

from the two RED cameras, 30 gigabytes from an uncompressed off board recorder

mounted on a DSLR as a third camera angle and 2 gigabytes from the audio recording

device. The running total of data ended up at 544 gigabytes of footage and audio. This

however was not even the full amount of the footage recorded for each show's

production; there was also b-roll footage shot and supplemental interviews recorded.

Each show would be close to 1.2 terabytes of data when it was fully complete. Most of

the b-roll I filmed would be recorded in slow-motion for aesthetic reasons, also

increasing the amount of data per minute even further by how slow I chose to record each

shot.

      This large amount of data led to problems when trying to properly store the

footage for editing and then later archiving after the show was complete. Normally I

would operate from a few hard drives to edit a project on. For example, I would utilize

two hard drives, one for backup and one for actually editing off of. Hard drives however

can be expensive, especially when you need them with the fastest ports currently

available, which for Macintosh computers, is the thunderbolt connection. Our set-up

would involve two separate hard drives one for backup and for one editing, both utilizing

Apple's thunderbolt port which gave us the ability to daisy chain our hard drives together

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[10] **REDCODE** RAW (.R3D) is a proprietary file format that efficiently encodes measurements from a camera's digital sensor in a way that maximizes post-production capabilities.

without being bottle necked.  I would also offload the footage from the cards they were

recorded on using RED's proprietary card reader, which had a USB3 port on it, allowing

us to maintain a fast workflow.   All of this setup was very important in keeping the

speed of the show at an efficient rate.  This however would have been a much slower

process only a few years ago when USB2.0 and firewire* were still the two main ports

used in video editing, it would have been to slow a process to work with raw footage

from the RED cinema cameras and keep the show at an efficient rate.

   After the show was complete and had aired on Fox Sports the crew and myself

would need some way of archiving each episode.  This became a problem due to each

show being around 1.2 terabytes of footage, and we had 36 shows to complete.  Hard

drives also start to have high failure rates after 4 years[11]and I wanted to have this show

and the original footage last a long span of time.  To circumvent this the production had

to figure out a cost efficient way of storing the show and for that device to also have a

long shelf life.  Eventually a Quantum TC-L52BN-AR 6Gbs SAS interface tape drive

that utilizes LTO5 Ultrium Tape was chosen to store the show on.  Each tape can hold

1.5-3 terabytes of data on it, depending on compression, and each tape only cost $29.99

in comparison a LaCie 3 terabyte thunderbolt hard drive cost approximately $289.99. [12]

This whole process felt odd to me at first, thinking in the terms of everything being

digital on hard drives and solid-state devices now, why would we archive the show on a

tape device?  I quickly learned that tape devices are extremely reliable in comparison to

hard drives and are also extremely cheap.  The shelf life of LTO tapes is measured at 30

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[11] http://www.extremetech.com/computing/170748-how-long-do-hard-drives-actually-live-for
[12] http://www.newegg.com/Product/Product.aspx?Item=N82E16840121083

years; this is also due to the system only being around that long.  I predict that the tapes

can last even further past this projected 30 year mark.

## CONCLUSIONS AND RECOMMENDATIONS

I learned more than I could have ever predicted during the production of *Hoosier Legends*. During the production of the show I was able to explore my two central objectives. The first objective being to devise, and streamline the production to post-production process with RAW image data. The second objective I completed was my goal to finish a national level documentary predicated on these methods, while being able to identify the necessary steps involved to produce the documentary as efficiently and inexpensively as possible. From this project I learned how to properly handle large amounts of data, proper storing and accessing files quickly for production, how to best utilize the technology that was available for me, how to setup the fastest offload/edit available for the footage, how to properly work with REDraw footage in post production, how to work in various color spaces, how to handle color grading on a quick turnaround time, and how to match cameras of various formats together to get the closest similar look possible, among many other lessons learned. Most importantly I learned how to efficiently capture high quality footage using a RAW based video format. I learned more from the complexities of this style of shooting than from the ease it made for production.

I learned a great amount during the production of *Hoosier Legends* because it was my first time ever producing a running television show and to add to that, the crew and myself were under such a short timeline and small budget to work with. All these factors added to the learning experience this production provided me. There can be many problems that occur when shooting in a RAW video format on a large-scale production if you are not properly prepared for it, but I believe the advantages it gives the filmmaker far out way the setbacks during production. I believe this is only the beginning of non-

fiction documentary filmmaking utilizing a RAW image workflow and we are soon to see

it being widely adapted from the amateur documentary filmmaker to the professional

level documentary filmmaker.

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APPENDIX A

Glossary

**Artifacting** – known as digital artifact when referring to computers and electronics is any error or glitch that occurs during a signal transmission or interpretation.

**Bayer Filter** – A Bayer array consists of alternating rows of red-green and blue green filters. Each primary color does not receive an equal fraction of the total area because the human eye is more sensitive to green light than both red and blue light.

**Bilinear Interpolation** – is an inexpensive interpolation algorithm, which assumes information from an average (arithmetic mean) of surrounding pixels.

**Bit Rate** - Bitrate, as the name implies, describes the rate at which bits are transferred from one location to another. In other words, it measures how much data is transmitted in a given amount of time. Bitrate is commonly measured in bits per second (bps), kilobits per second (Kbps), or megabits per second (Mbps).

**Camera Operator** - a photographer who operates a movie camera.

**Close Up Shot** - A certain feature or part of the subject takes up the whole frame.

**Color Grading** - The process of altering or enhancing the color of an image to seamlessly blend cuts together in a scene, remove unintended mistakes (e.g. overexposure of highlights) or for creative effect. Also known as color correction or color timing.

**Color Model** - A color model is a system for creating a full range of colors from a small set of primary colors. There are two types of color models: additive and subtractive. Additive color models use light to display color, while subtractive color models use printing inks. The most common color models that graphic designers work with are the CMYK model for printing and the RGB model for computer display.

**Color-Rendering Index** - in general terms, Color Rendering Index (CRI) is a measure of a light source's ability to show object colors "realistically" or "naturally" compared to a familiar reference source, either incandescent light or daylight.

**Communication Protocol** - All communications between devices require that the devices agree on the format of the data. The set of rules defining a format is called a protocol.

**CMYK** – a colour model that describes each colour in terms of the quantity of each secondary colour (cyan, magenta, yellow), and "key" (black) it contains.

**Daisy-Chain** - A hardware configuration in which devices are connected one to another in a series.

**Demosaicing** – is the process of translating the Bayer array of primary colors into a final image which contains full color information at each pixel.

**Director of Photography** – the person who is responsible for all operations concerning camera work and lighting during the production of a film.

**Edge-Sensing Bilinear Interpolation** – is a so called "adaptive" algorithm, which analyzes the image and chooses an interpolation formula based on surrounding pixels.

**Firewire** – a proprietary name for the internationally agreed standard IEEE1394, a high-performance interface which allows for the connection of peripherals such as modems, printers, and mass storage devices.

**Frame Rate** - Video is captured and played back as a sequence of static (still) images, each image being one "frame." The frame rate is the number of these frames per second. For example, movie film is shot at 24 frames per second (fps), while NTSC video is shot at 29.97 interlaced fps, and high-definition video at 30 and 60 fps.

**Fresnel** - a lens that has a surface consisting of a concentric series of simple lens sections so that a thin lens with a short focal length and large diameter is possible and that is used especially for spotlights.

**Gaffer** – a person who is in charge of the lights that are used when making a movie, television, etc.

**Grip** - worker in a camera crew or a stagehand who shifts sets and props, etc.

**Hair light** - The hair light is a light that is often suspended from the ceiling or on a very tall light stand. It looks straight down on the staging area, and is designed to subtly light the subject's hair, creating highlights and shadows among the strands.

**Hard Disk Drive** - abbreviated as HD or HDD, the hard drive is the computer's main storage media device that permanently stores all data on the computer. The hard drive was first introduced on September 13, 1956 and consists of one or more hard drive platters inside of air sealed casing.

**Highlight Detail** - re the lightest areas of an image, therefore the parts that have the most light hitting it.  If something has too many highlights, we may say that it is overexposed and the area is lacking in detail.

**ISO** – the numerical exposure index of a photographic film under the system adopted by the International Standardization Organization, used to indicate the light sensitivity of the film's emulsion.

**Kelvin Scale** - The colour temperature of light is measured on the Kelvin scale (K).

**Key light** – (in photography or motion pictures) the main light that illuminates the subject being photographed or filmed.

**Kino Flo** – color corrected fluorescent tubes that are extremely lightweight, compact, soft source and flicker free source of light.

**Log-C** - The Log C curve is a logarithmic encoding of the scene, meaning that the relation between exposure measured in stops and the signal is constant over a wide range. Each stop of exposure increases the signal by the same amount. The overall shape of the Log C curve is similar to the exposure curves of film negatives. Because of fundamental differences between a sensor and negative film, however, the color characteristics remain different.

**Lossy Compression** - results in lost data and quality from the original version. Lossy compression is typically associated with image files, such as JPEGs, but can also be used for audio files, like MP3s or AAC files.

**Medium Shot** - Shows some part of the subject in more detail while still giving an impression of the whole subject.  (http://www.mediacollege.com/video/shots/)

**Midtone Detail** - show the middle tones of an image – the colours that are in-between.  For example, if we had a black and white image, the midtone would be grey – somewhere between the two.

**Nearest-Neighbor Interpolation** – simply takes the spatially-closest data point and assumes its value.

**Photochemical** - of, relating to, or resulting from the chemical action of radiant energy and especially light.

**Production Assistant** - A production assistant (P.A.) is the entry-level position on a film crew. P.A.s provide support and assistance to almost all areas of the production, and can also work for specific departments.

**RAW** - A raw file is a record of the data captured by the sensor. While there are many different ways of encoding this raw sensor data into a raw image file, in each case the file records the unprocessed sensor data.

**RGB** – Red, Green, Blue. The three colours of light which can be mixed to produce any colour.

**Shadow Detail** - are the darkest areas of a photograph. A shadow is also devoid of color; it could be the black in a photograph or just the areas that carry little light. An image with too many shadows may be underexposed, and will not show much detail, although this can normally be adjusted.

**Smooth Hue Transition Interpolation** – smooth hue transition takes advantage of this by treating the green channel as luminance channel, and using relative intensities of blue and red to green to determine color intensity.

**Solid State Drive** – (SSD) is a storage device that stores persistent data on solid-state flash memory. SSDs actually aren't hard drives at all, in the traditional sense of the term, as there are no moving parts involved.

**Stacked RGB** – this filter array uses a single sensor to record all three colors at each photosite at once.

**Striped RGB** – this groups three photosites into each pixel, similar to how the photosphors on older CRT televisions were arranged. The initial motivation was to be able to read these into RGB pixels directly, without the need for a demosaicing algorithm. However, without demosaicing, the actual resolution often ends up being less than a third of what the photosite count alone would lead one to believe. Furthermore, since each color is in a different position, these sensors are prone to rainbow artifacts when read into RGB values directly.

**Three-Chip RGB and Prism** – this filter array achieves an impressive feat of recording the precise location of each color of light without using color filters. However, this greatly increases costs by tripling the sensor area with three chips. To keep prices competitive, the size of each sensor is often reduced, but this ends up requiring non-standard lenses and reducing the light-gathering area. Using a prism to direct light also has the potential to introduce new image artifacts, since light may not refract as intended.

**Thunderbolt** - Thunderbolt is a revolutionary I/O technology that supports high-resolution displays and high-performance data devices through a single, compact port. Thunderbolt gives you two channels on the same connector with 10Gb/s of throughput in both directions.

**Tonal Range** - a term used to describe the range of brightness levels in an image from the darkest to the lightest.

**Tungsten Fresnel** – tungsten lamps are just bigger versions of ordinary household bulbs; they all have a filament of tungsten wire just as invented by Thomas Edison.

**Ultra HD** - (also known as "Ultra High Definition" / "Super Hi-Vision" / "Ultra HDTV" / "UHD" / "UHDTV" / "4K" / "8K"), is a video format conceptualized by the Japanese public broadcasting network, NHK. On October 17, 2012, The Consumer Electronics Association (CEA) announced that the official term "Ultra HD" would be used for any

display with a 16 x 9 ratio with at least 1 digital input cable carrying a minimum resolution of 3,840 x 2,160 square pixels.

**USB 3.0** - The third generation of the USB interface introduced in 2008. Called "SuperSpeed USB 3.0" (SS USB), it provides a 10x increase from 480 Mbps to 4.8 Gbps and also reduces CPU overhead by no longer continuously polling attached devices.
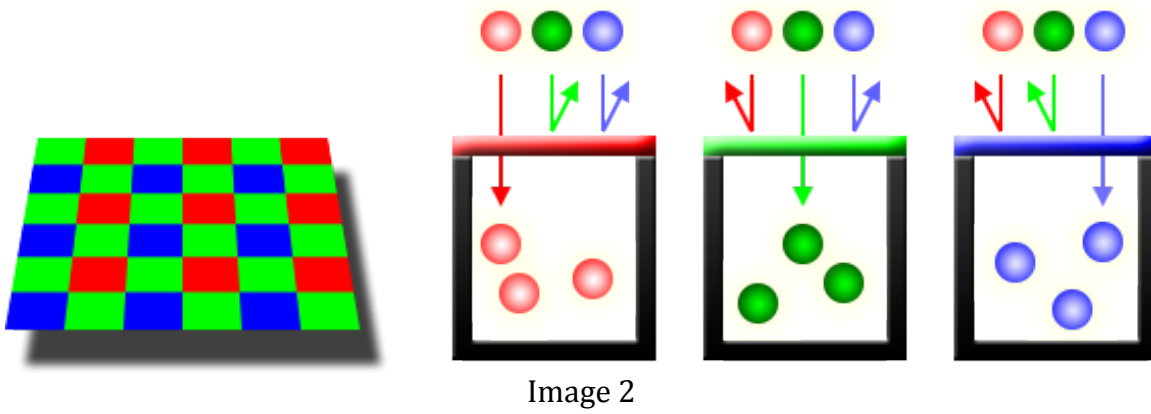
**White Balance** - White balance is a feature many digital cameras and video cameras use to accurately balance color. It defines what the color white looks like in specific lighting conditions, which also affects the hue of all other colors.

**Appendix B**

Technical Images
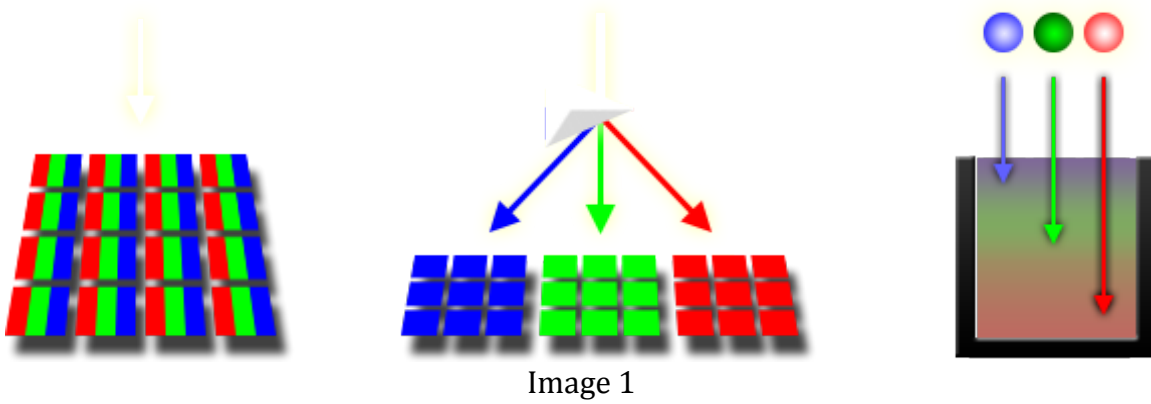


Image 1

*Comparative Filter Array* (Image). Retrieved March 24, 2014, from
http://www.red.com/learn/red-101/bayer-sensor-strategy



Image 2

*Bayer Array* (Image). Retrieved March 24, 2014, from
http://www.red.com/learn/red-101/bayer-sensor-strategy
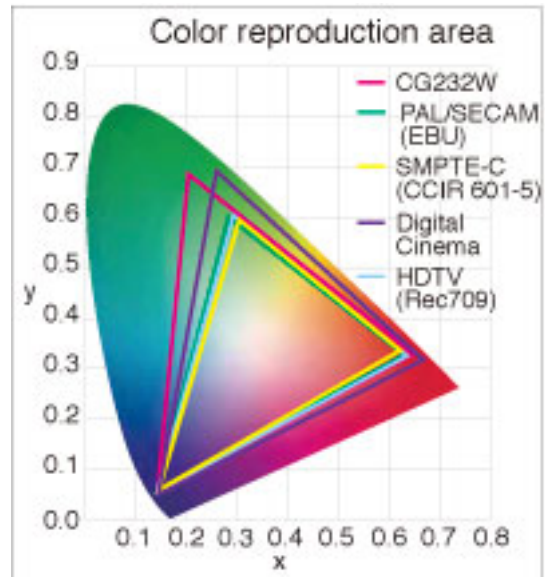
Image 3

*Preset Color Modes* (Image). Retrieved March 24, 2014, from
        http://www.rsgsolutions.co.in/images/preset-color-modes.jpg



Image 4

*RGB Additive Color Model* (Image). Retrieved March 24, 2014, from
        http://www.designersinsights.com/designer-resources/understanding-
        color-models
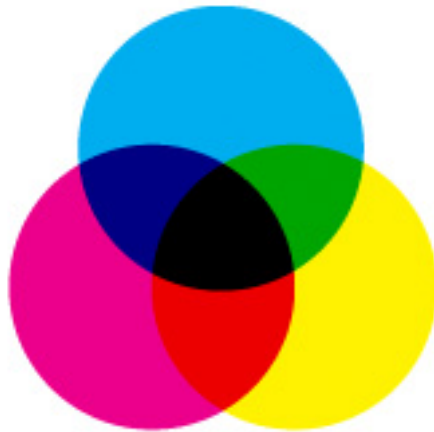
Image 5

*CMYK Subtractive Color Model* (Image). Retrieved March 24, 2014, from
     http://www.designersinsights.com/designer-resources/understanding-
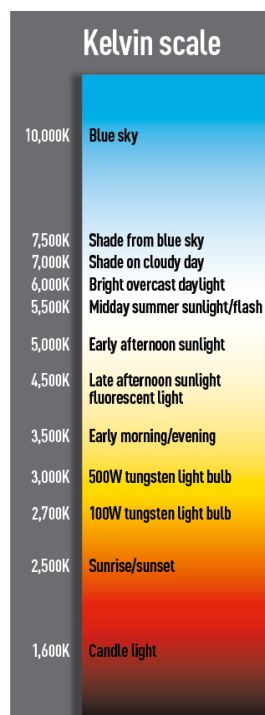     color-models



Image 6

*Kelvin Scale* (Image). Retrieved March 24, 2014, from
     http://www.amateurphotographer.co.uk/helpadvice/technical/529114/kel
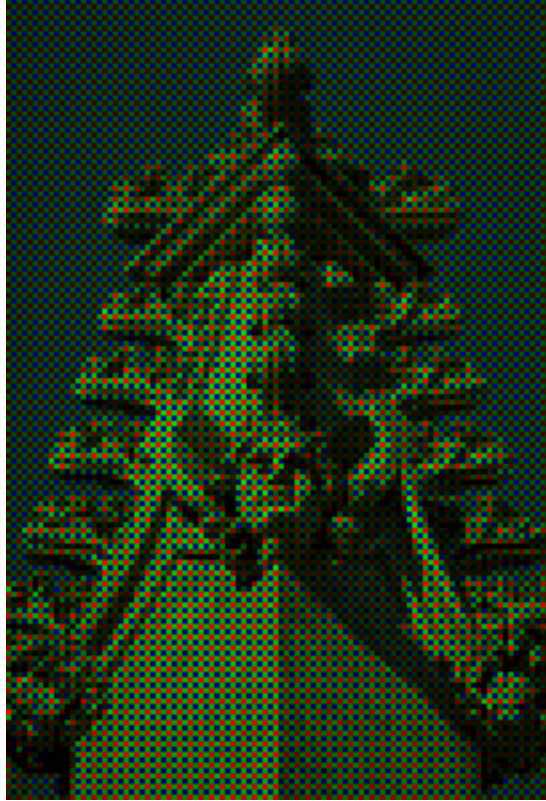     vin-scale-chart

Image 7

*Bayer Image* (Image). Retrieved March 24, 2014, from
http://www.cambridgeincolour.com/tutorials/camera-sensors.htm

Image 8

*Final Image* (Image). Retrieved March 24, 2014, from
http://www.cambridgeincolour.com/tutorials/camera-sensors.htm