RAW WORKFLOWS:
FROM CAMERA TO POST

Introduction

- What is a RAW file format, and what cameras shoot to these formats?
- How does working with RAW file-format cameras change the way I shoot?
- What changes are happening inside the camera I need to be aware of, and what happens when I go into post?
- What are the available post paths? Is there just one, or are there many ways to reach my end goals?
- What post tools support RAW file format workflows?
- How do RAW codecs like CineForm RAW enable me to work faster and with more efficiency?

What is a RAW file?

- In simplest terms is the native digital data off the sensor's A/D converter with no further destructive DSP processing applied
- Derived from a photometrically linear data source, or can be reconstructed to produce data that directly correspond to the light that was captured by the sensor at the time of exposure (i.e., LOG->Lin reverse LUT)

Photometrically Linear

Doubling of light means doubling of digitally encoded value

What is a RAW file?

- In film-analogy would be termed a “digital negative” because it is a latent representation of the light that was captured by the sensor (up to the limit of the full-well capacity of the sensor)
- “RAW” cameras include Thomson Viper, Arri D-20, Dalsa Evolution 4K, Silicon Imaging SI-2K, Red One, Vision Research Phantom, noXHD, Reel-Stream
- “Quasi-RAW” cameras include the Panavision Genesis

In-Camera Processing

- Most non-RAW cameras on the market record to 8-bit YUV formats that “bake” all color-processing operations into the final file format
- 8-bit encoding along with compression limits dynamic range in post – must maximize dynamic range distribution at the sensor head
- All processing stages are destructive/non-reversible

RAW File "Processing"

- Most RAW format cameras on the market are single-sensor and use Bayer color filter arrays to create color
- Bayer data cannot be viewed natively – must be processed into color information

Single-sensor cameras "see" monochrome

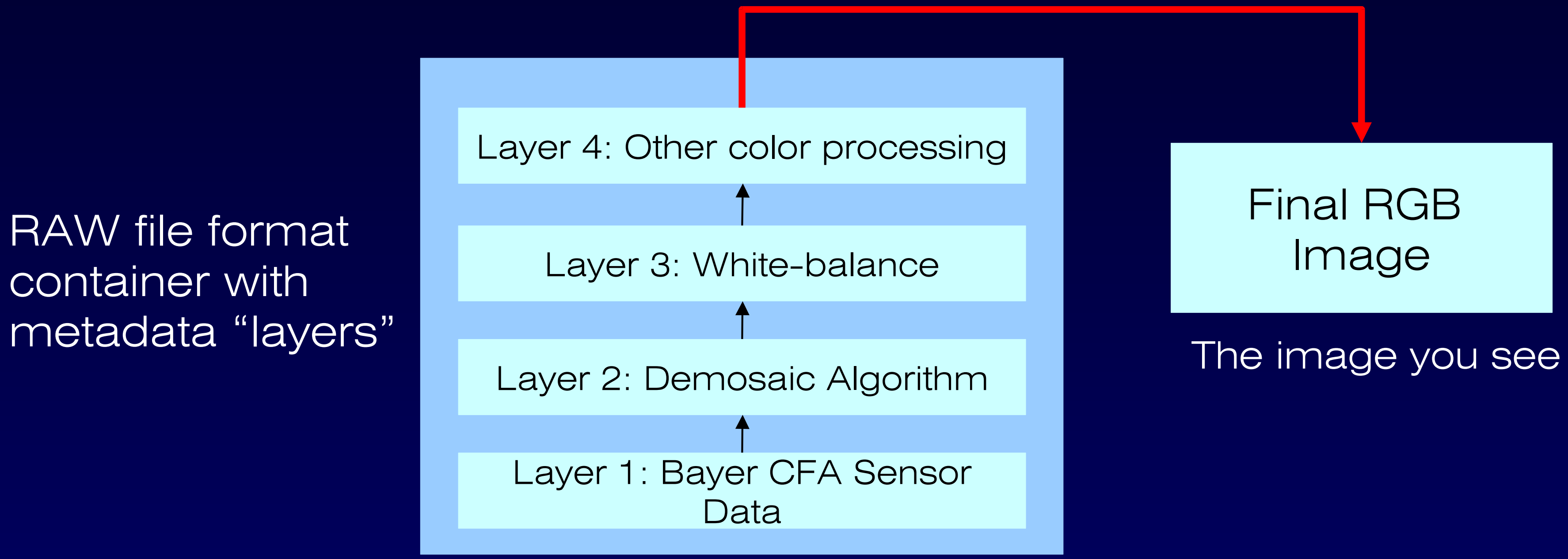
Not noise-Bayer CFA

Demosaicing produces color image

Loss of resolution about 30% theoretical resolution limit with good Bayer reconstruction algorithm

RAW File "Processing"

- In addition to the demosaicing process to produce RGB images, other color transforms need to be applied to data in order to get a "nice" final image.
- In Bayer RAW files, these color transforms are saved as metadata, or applied as filters during reconstruction



RAW Compression

- All forms of compression are typically optimized for the human visual system->throwing away what we can't see

- Forms of Compression
  - 12-bit Linear -> 10-bit LOG
  - Visually lossless wavelet (CineForm RAW)

- You want non-linear curve (LOG) on compressed material to preserve the maximum amount of information in both shadows and highlights
  - Compressing linear data simply wastes bits encoding noise in the highlights and ruins shadow details-preventing this loss means higher data-rate

Dynamic Range

- Determined by the SNR/noise floor of the sensor
- High-bit depth A/D converter (12+) useless if low SNR (<48db) . . . you're just digitizing noise
  - Still better dynamic range than results of 8-bit encoding and compression

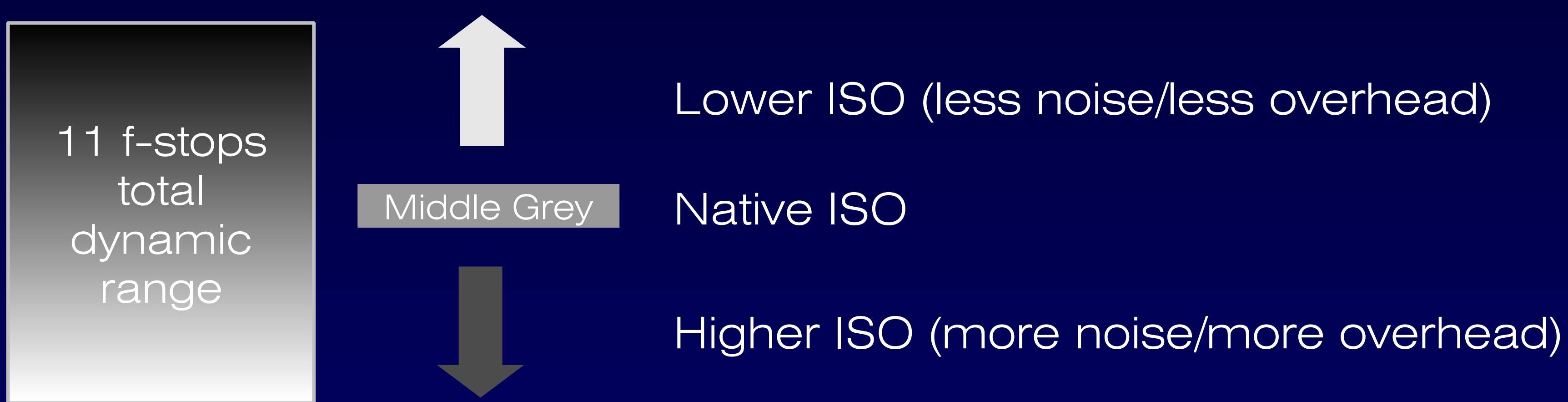
No free lunch . . . junk going in means junk coming out!

Dynamic Range

- Dynamic Range "overhead" vs. Shadow Detail:
  - With good sensor, you will get around 11 f-stops of dynamic range available in RAW file.
  - Film has large amount of over-exposure latitude
  - Digital overhead again determined by SNR of sensor
  - Better SNR means more overhead room and higher native ISO

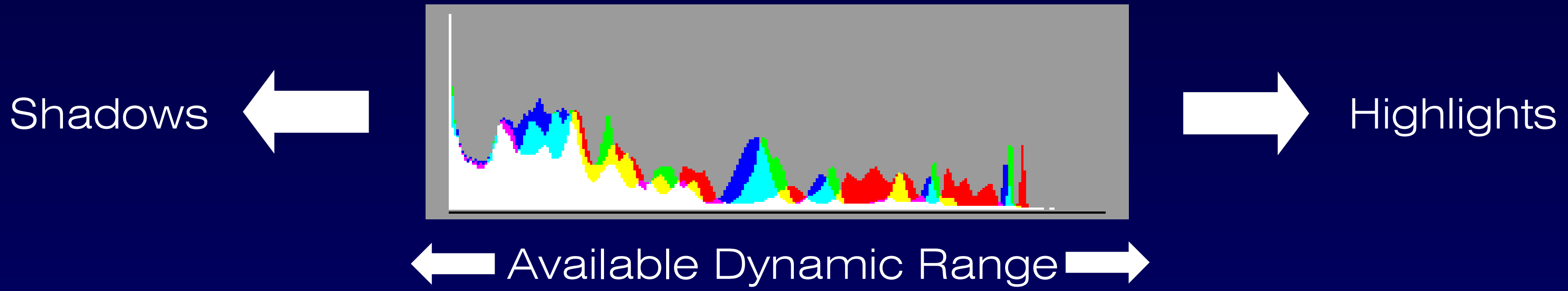
Dynamic Range

- Dynamic Range "overhead" vs. Shadow Detail:
  - RAW files are "un-developed"
    - Exposing brighter means "printing-down" in post
    - Exposing darker means "pushing" in post
  - You can trade ISO for digital overhead and use post tools or View LUT's to normalize the exposure . . . all the same dynamic range from the A/D converter



Exposure Tools

- With ability to “print-up” or “print-down” the digital negative in post, proper exposure depends on maximizing the SNR of the captured image without clipping
- Histograms
  - Distribution graph of the values being captured by the A/D converter
  - shows your use of the “dynamic range bandwidth” available in the signal (waveforms not as optimal)



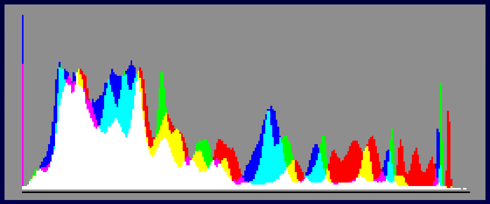
Exposure Tools

- With Histograms, you want to "expose to the right"
  - Get a good "thick" digital negative with maximized signal-to-noise ratio for the scene, giving you more room to work in post
  - With high-bit-depth RAW files, unused areas in shadows are okay (over-exposure), but don't clip

Bad Exposure

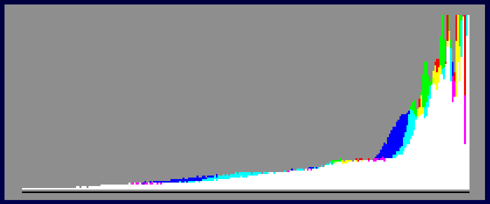
"Thin", under-exposed digital negative. You will need to"push" in post (gain) which will be noisy

Good Exposure



Good use of the dynamic range of the sensor, capturing detail without clipping

Highlight Clipping



It's okay to "over-expose" with high-bit depth files to get cleaner images like over-exposing film, but don't clip

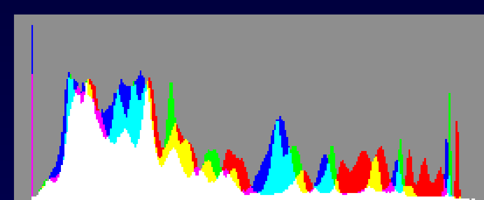
Exposure Tools

- With Histograms, you want to “expose to the right”
  - Typically find scenario to “over-expose” when scene dynamic range is less than sensor dynamic range
  - Rather than shooting at the sensor's native ISO, maximize SNR by over-exposing (but not clipping) and then “printing-down” in post

Bad Exposure

“Thin”, under-exposed digital negative. You will need to“push” in post (gain) which will be noisy

Good Exposure



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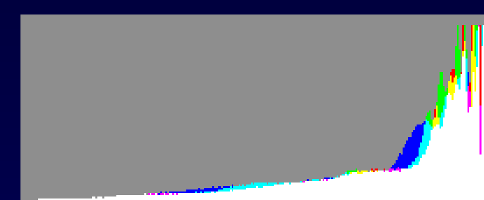
Highlight Clipping



It's okay to “over-expose” with high-bit depth files to get cleaner images like over-exposing film, but don't clip

View LUT's

- View LUT's are to the digital negative as a print stock or answer print is to a normal film negative
  - RAW files are are either photometrically linear or LOG encoded - need View LUT's to look “normal” on-screen

RAW 10-bit LOG

View LUT

“Normal” Contrast/Saturation

View LUT's

- View LUT's provide the ability to "see" the negative from the perspective of the final print live on-set
  - Use View LUT's to normalize footage, "printing-up" or "printing-down" to achieve a finalized "look" for the intended visual target without the guesswork
  - It's okay if the view LUT's clip data to get good contrast . . . they are non-destructive "layers"
- In film, final look was in the D.P.'s mind . . . view LUT's let you share creative vision with the rest of your crew

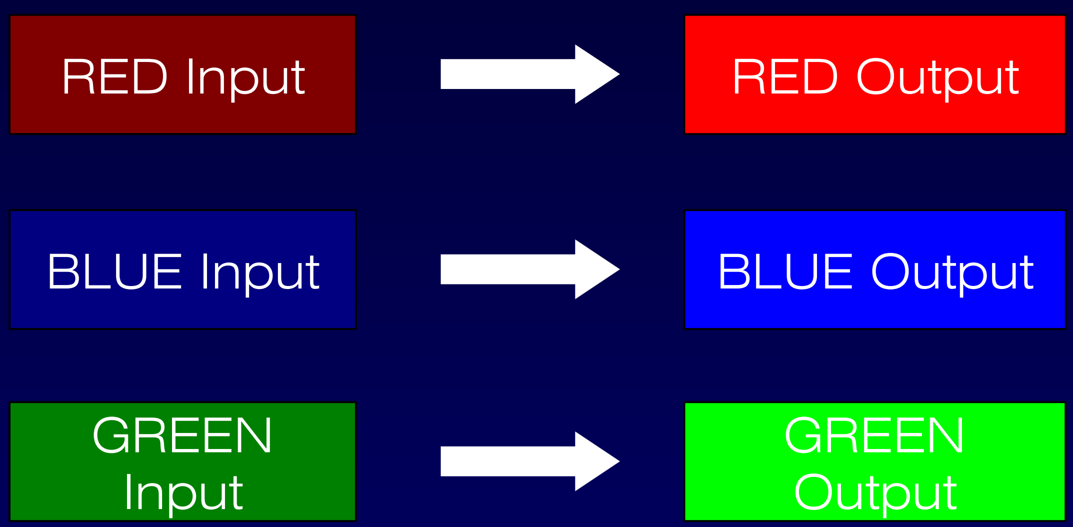
RAW
10-bit LOG

View LUT

Creative "Look"

View LUT's

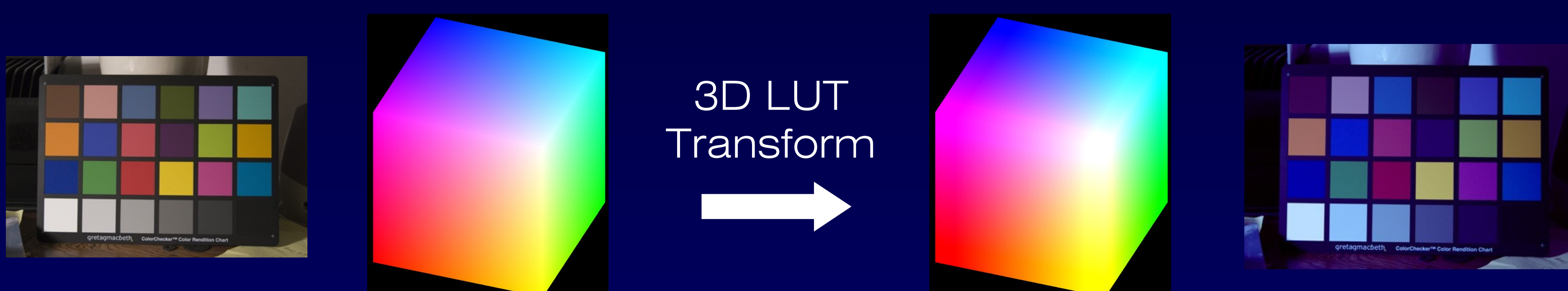
- Two Types:
  - 1-Dimensional – per-channel R, G, B, LUT's
  - A change in one channel does not affect the others
  - Can modify contrast, gamma, color offsets, white-balance, and gain
  - Like Photoshop curves



All adjustments in one channel are confined to that channel

View LUT's

- Two Types:
  - 3-Dimensional – color “cubes”; maps RGB->R'G'B'
  - Can describe any series of non-linear transforms
  - In addition to 1D LUT's, can also describe saturation, hue transforms, matrix calculations, gamut-mapping, and target color-profile emulation
  - Would be like “baking” a perfect color-correction in Photoshop so it can always be repeated

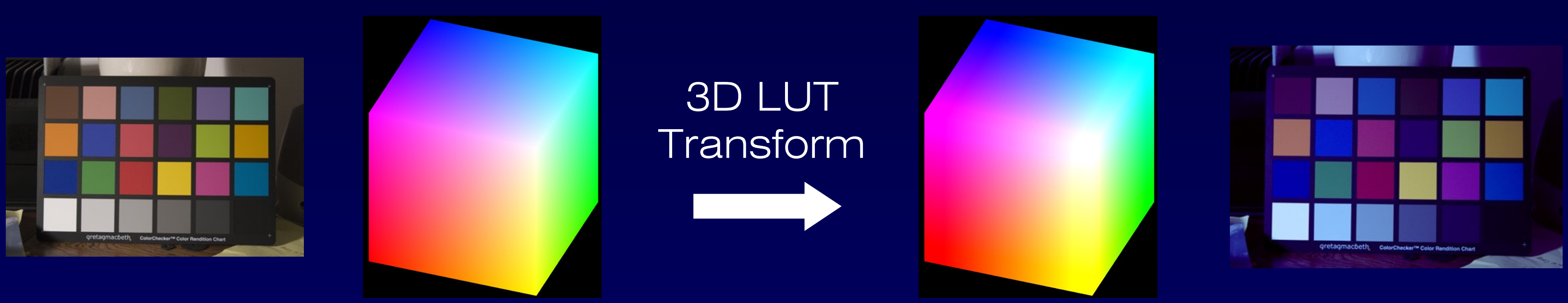


View LUT's

- LUT Sizes:
  - 1-Dimensional LUT's have a 1:1 correspondence between the bit-depth and the number of entries
  - 3-D LUT's must be interpolated from a subset, or else the LUT could easily go over a gigabyte in size
    - 8x8x8->too small for most transforms
    - 16x16x16->good size for previews
    - 64x64x64->rendering quality

View LUT's

- LUT preview devices:
  - Cinetal: 1-D and 3-D up to 64x64x64
  - Thomson LUTher: 1-D and 3-D up to 128x128x128
  - Ecinema Systems: 1-D and 3-D
  - HD-Link (Blackmagic): 1-D
  - Silicon Imaging SI-2K: 3-D up to 64x64x64



Floating Point vs. Integers

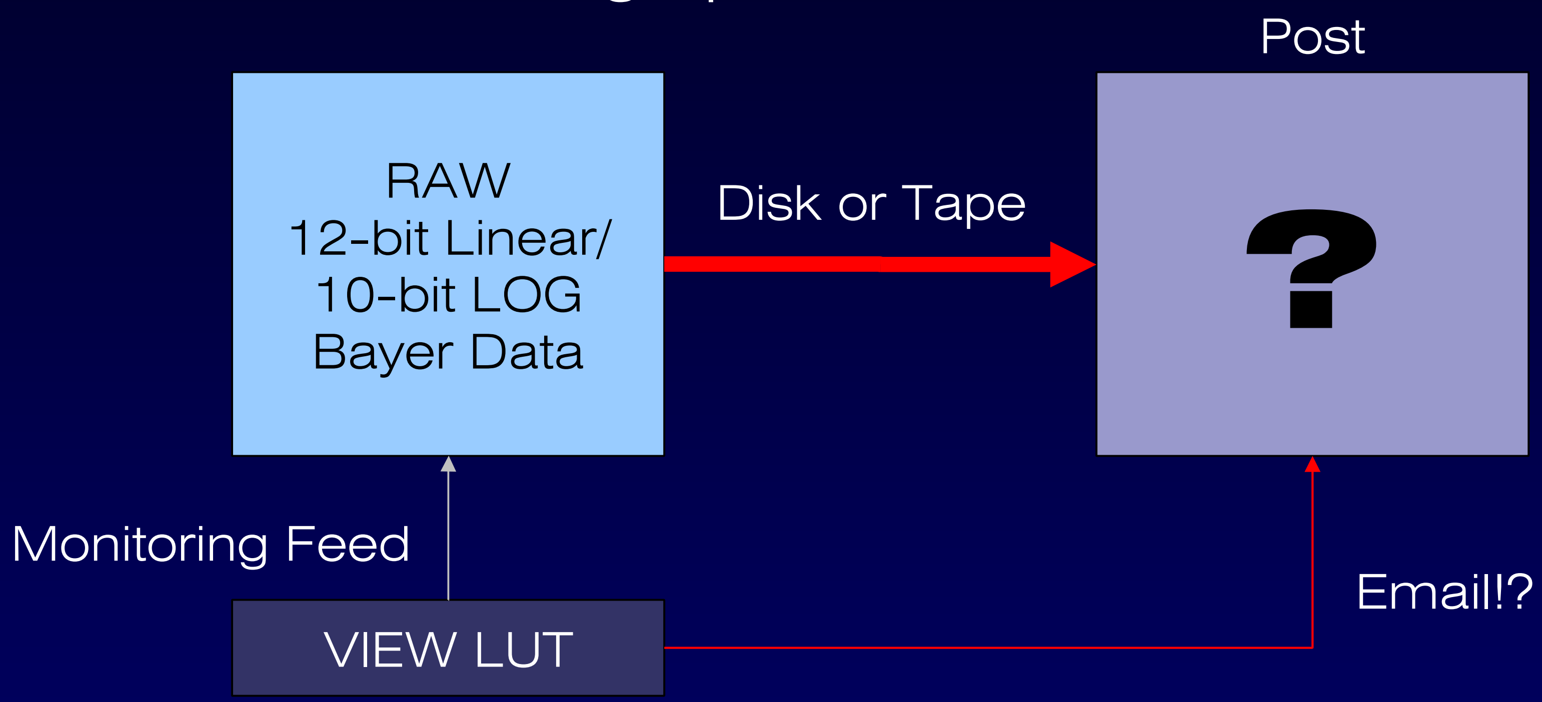
- LUT's can be both an assembly of floating point or discreet integer values
- Discreet integers describe from 0->Max bit-depth for black->white
  - Cannot describe super-white/super-black values, although some cases like Cineon use a subset of values for black->white and the rest for over/under
- 32-bit floating describes 2^32 number of values where 0->1.0 is black->white
  - Any of the possible 2^32 values can fall in the 0->1.0 range, or above and below . . . allows for extremely high precision and unlimited over/under values

Floating Point vs. Integers

- Discreet integer LUT's are good for on-set view LUT's
- If bringing your on-set view LUT into post-production, you'll want a floating point LUT to prevent clipping of the source data and allow the post application access to over/under values
- Examples of Floating Point LUT's:
  - IRIDAS
  - Truelight
  - CineSpace (Rising Sun Research)

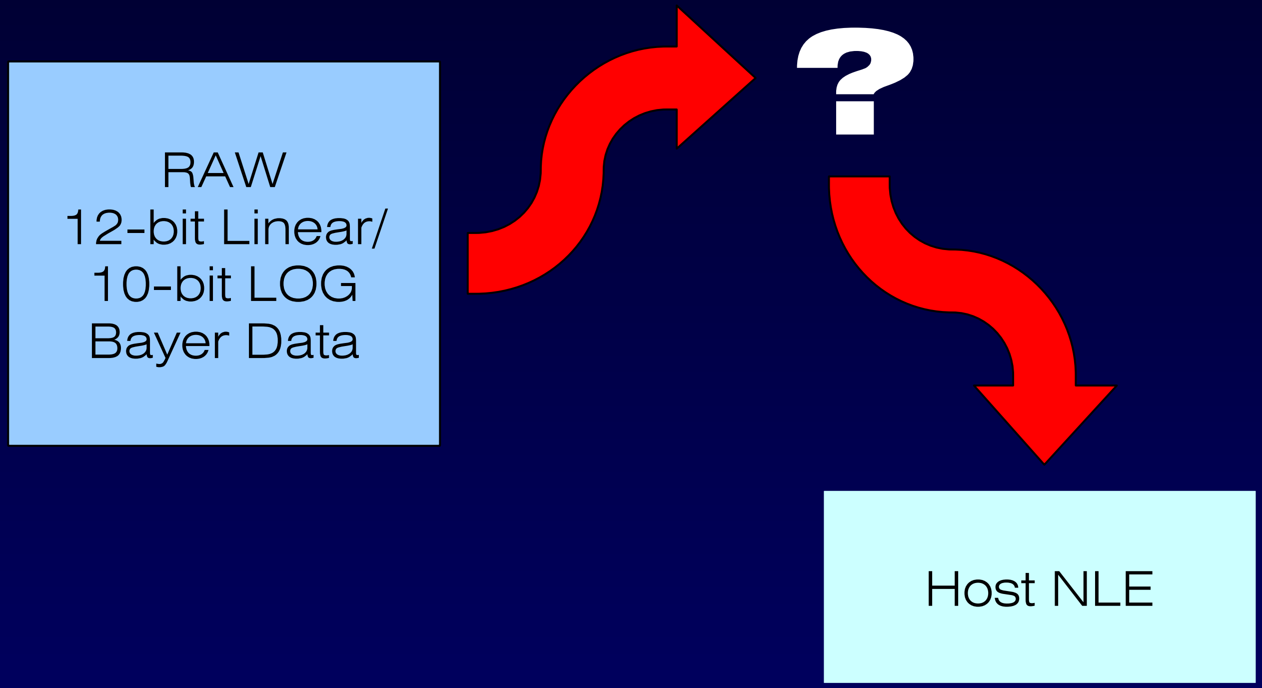
Into Post-Production . . .

- You've got this great, wide-dynamic range “digital negative” straight from the sensor's A/D converter . . . now what?
  - It looked great on the set, but how do you ensure it makes it through post?



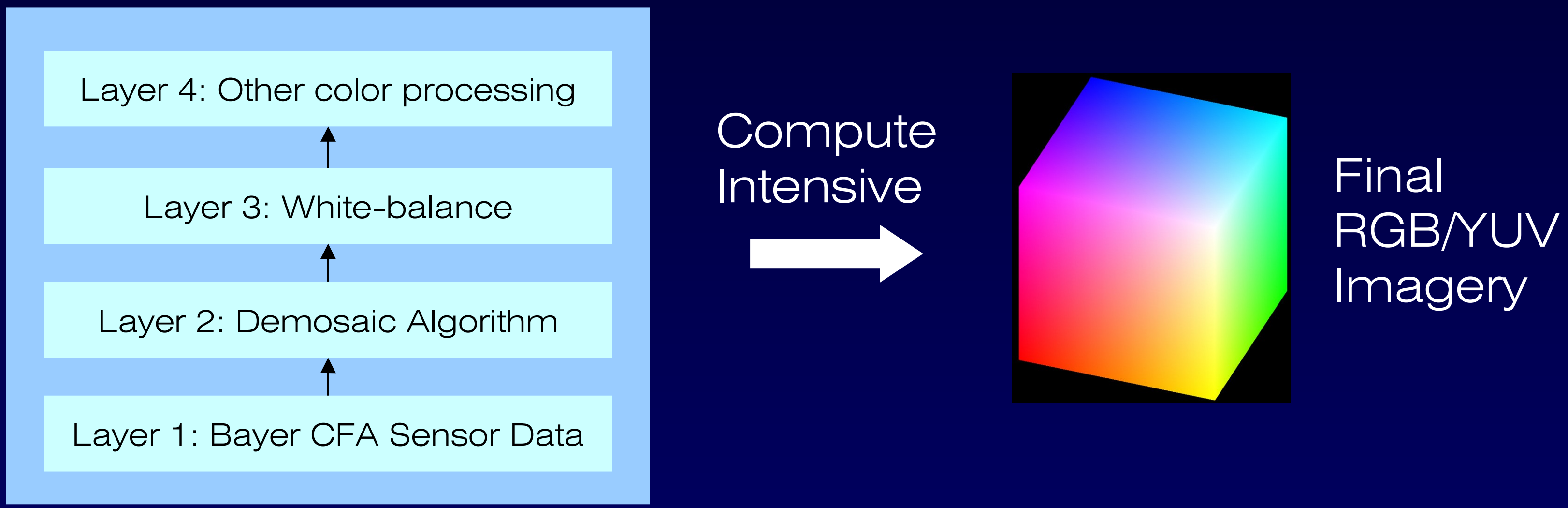
Into Post-Production . . .

- Most programs, including all current NLE's, do not support RAW Bayer file formats natively
  - Can't recognize the data and metadata, and can't natively render that information on-the-fly into usable RGB/YUV data



RAW Bayer +/-'s

- RAW processing pipeline re-duplicates the DSP electronics of the camera . . . DSP operations saved as non-destructive metadata, so almost unlimited flexibility
  - Downside is very compute-intensive . . . most cameras have dedicated FPGA's for these tasks
- Like film negative, you can't view the RAW Bayer “digital negative” directly either; must be “developed”

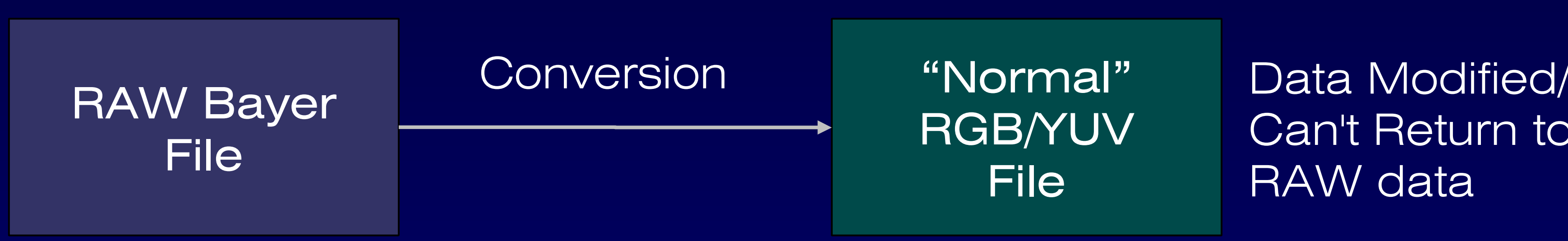


Workflow Solutions

- Three workflow solutions to the problem for host applications not having native support for RAW
  - RAW conversion applications (Redcine, Dalsa, Vision Research) for pre-processing RAW->RGB
  - Custom RAW Importers
    - Adobe Camera RAW in After Effects
    - Assimilate Scratch
    - IRIDAS Framecycler (real-time GPU previews)
    - Quantel (Arri D20)
  - Codec-Level management
    - CineForm RAW
    - Redcode RAW

Raw Conversion Apps

- Interpret the color metadata information in the RAW file and renders the RAW Bayer data to RGB formats natively supported by NLE/compositing apps
- Flexible in the number of file formats supported
- Major negative is that all metadata information is lost as it is “baked” into the destination file format, and Bayer data is gone when converted into RGB/YUV
- Akin to telecine operation where wide-dynamic range digital negative is color-corrected and then fixed into the limited dynamic range of tape

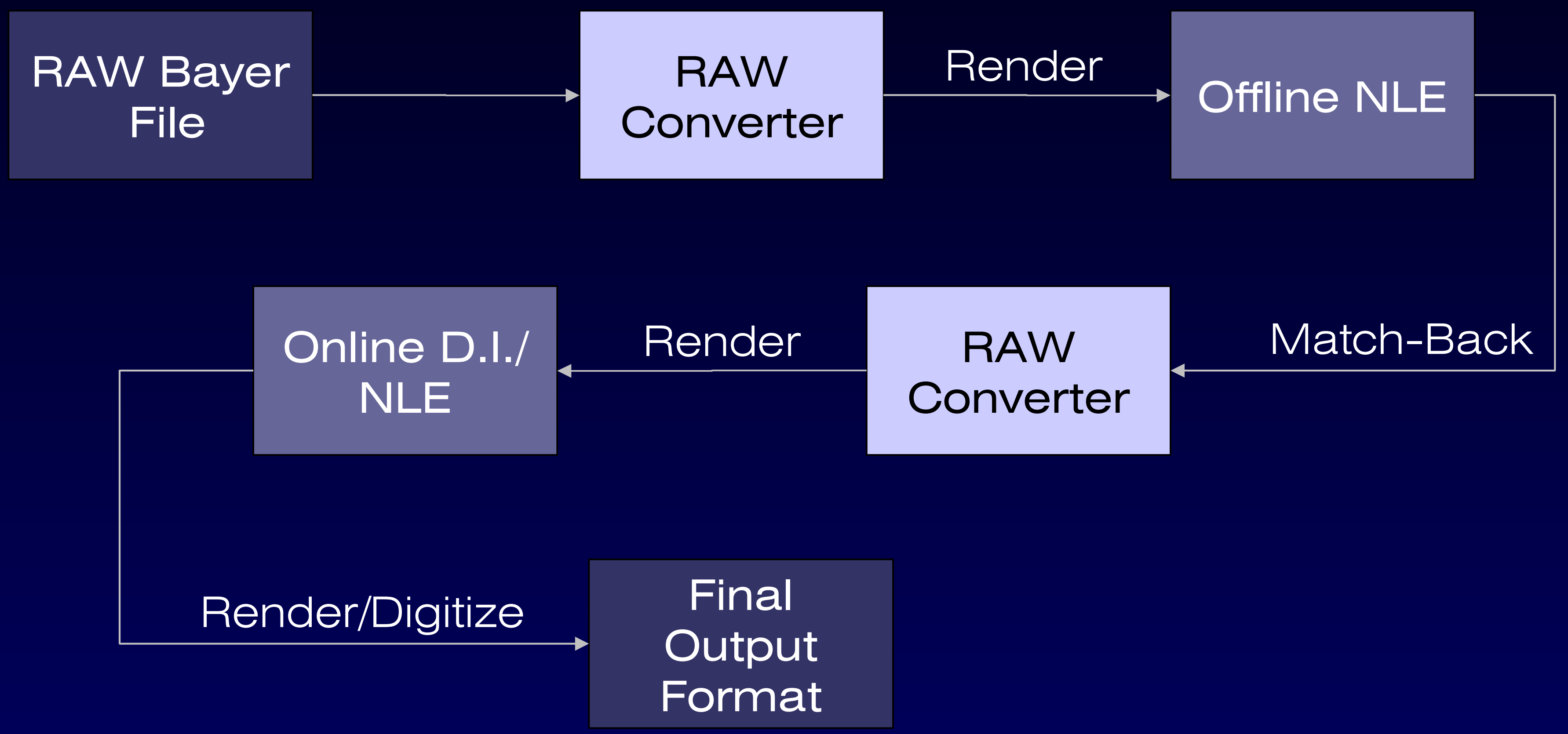


Raw Conversion Apps

- If going through DI stage, need to render a “one-light” pass . . . too radical an adjustment will limit modifications later
  - If the output codec is highly compressed (DVCProHD), should do as much color-correction as possible initially to maximize dynamic range
- If render target is a non-realtime codec (i.e., uncompressed), must also render proxy for NLE editor
- Render, render, render (get a render farm)!

Raw Conversion Apps

- Example of entire post process with RAW conversion app:

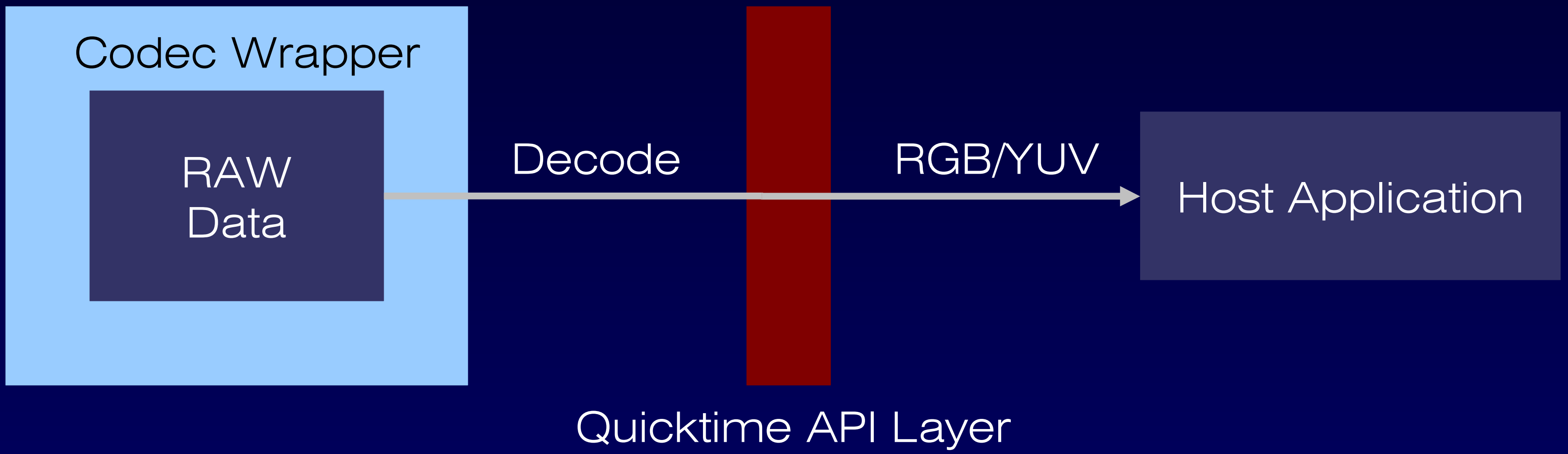


Custom RAW Importers

- Can work great for the host application
  - Allows the user to see the RAW Bayer files “natively” and interact with them as they would with any other format in the host app
- A Negative when required to share data between apps that do not support RAW files
  - Apps with the RAW importer become glorified RAW converters at this point
- Often need a custom RAW importer per RAW file format since there is no RAW Bayer file format standards

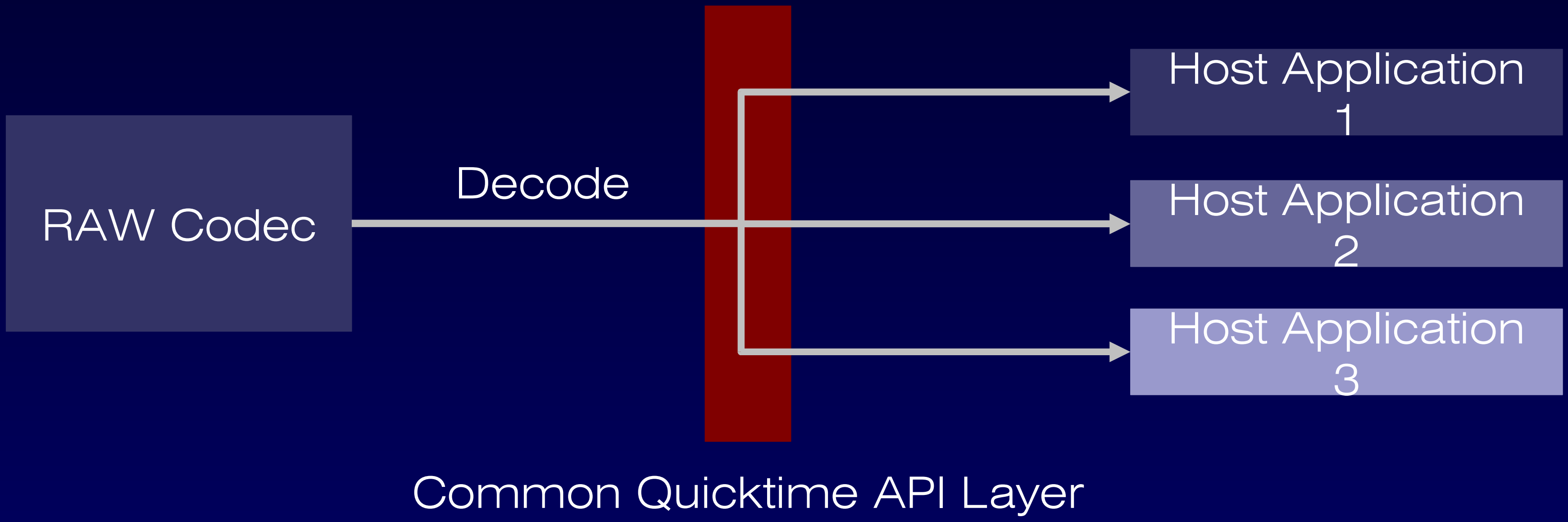
Codec-Level Support

- Most flexible approach
  - low-level codec API (like Quicktime) acts as a universal buffer between the RAW Bayer files and the host applications
  - Users can interact with files wrapped in RAW Bayer codec like any other codec-wrapped movie file



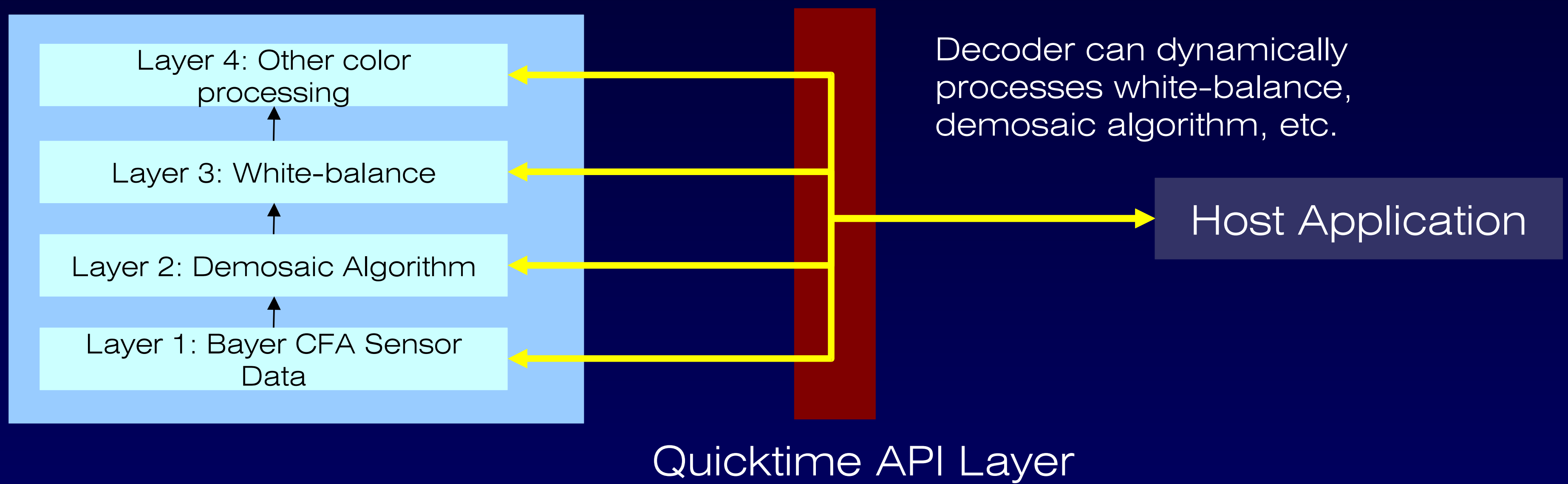
Codec-Level Support

- Common codec API's allows for RAW Bayer data to move natively between applications without conversion
- Similar to current data-management techniques of “native HDV” editing (i.e., nobody ever interacts with native MPEG-2 GOP . . . only I-frames after decode)



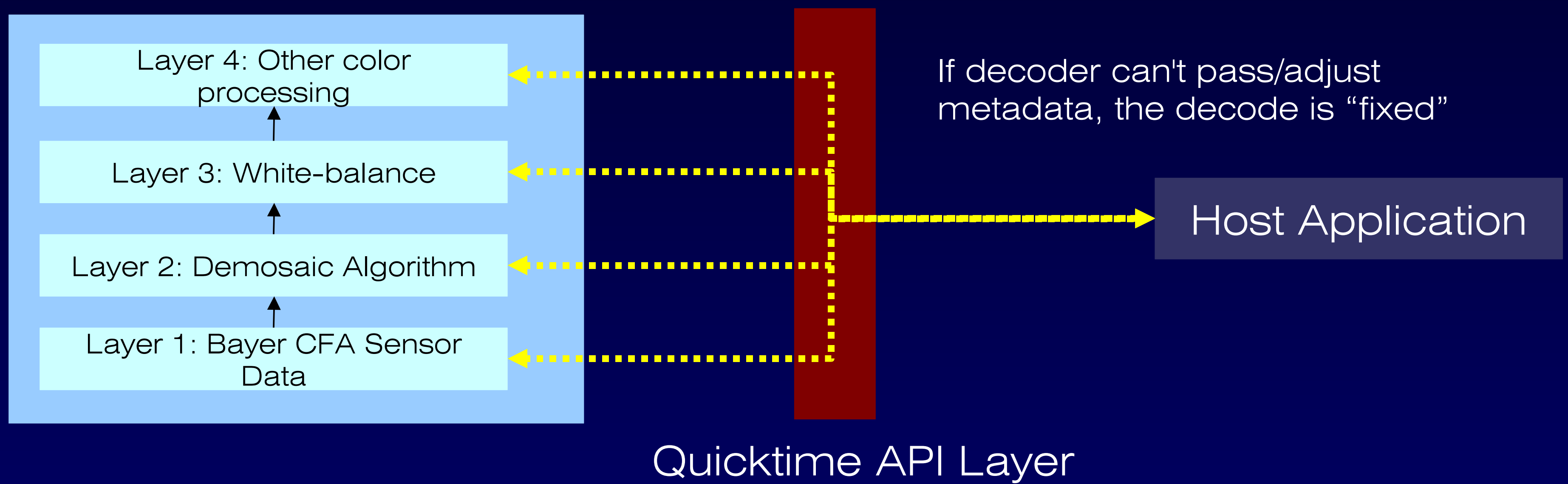
Codec-Level Support

- Metadata that is embedded in the RAW file can, through the codec API, be passed to the host application
  - Files can act like any other RGB/YUV “native” files in host application but can also have special hooks to interactively process/adjust non-destructive RAW Bayer metadata (two-way street)



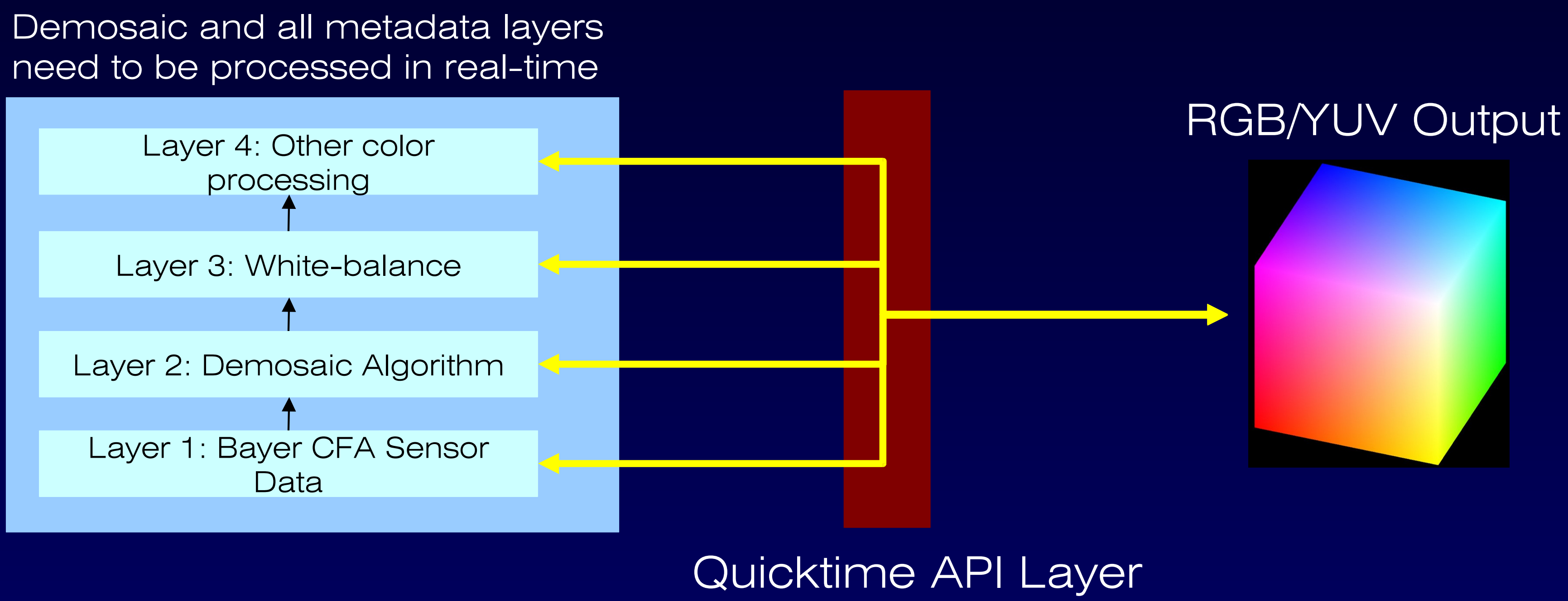
Codec-Level Support

- Limitations can be in how much metadata the codec supports, and how many parameters can be passed/adjusted by the host application for dynamic decodes
  - Metadata by it's nature is non-destructive, but if it the host does not have access to it, then it's a “fixed” variable, and you lose flexibility of RAW



Codec-Level Support

- Second limitation is how fast the codec can decode – if not real-time, need offline/online workflow
  - RAW Bayer decodes can be even more complex than CPU-intensive codecs like JPEG-2000 or H.264 MPEG-4



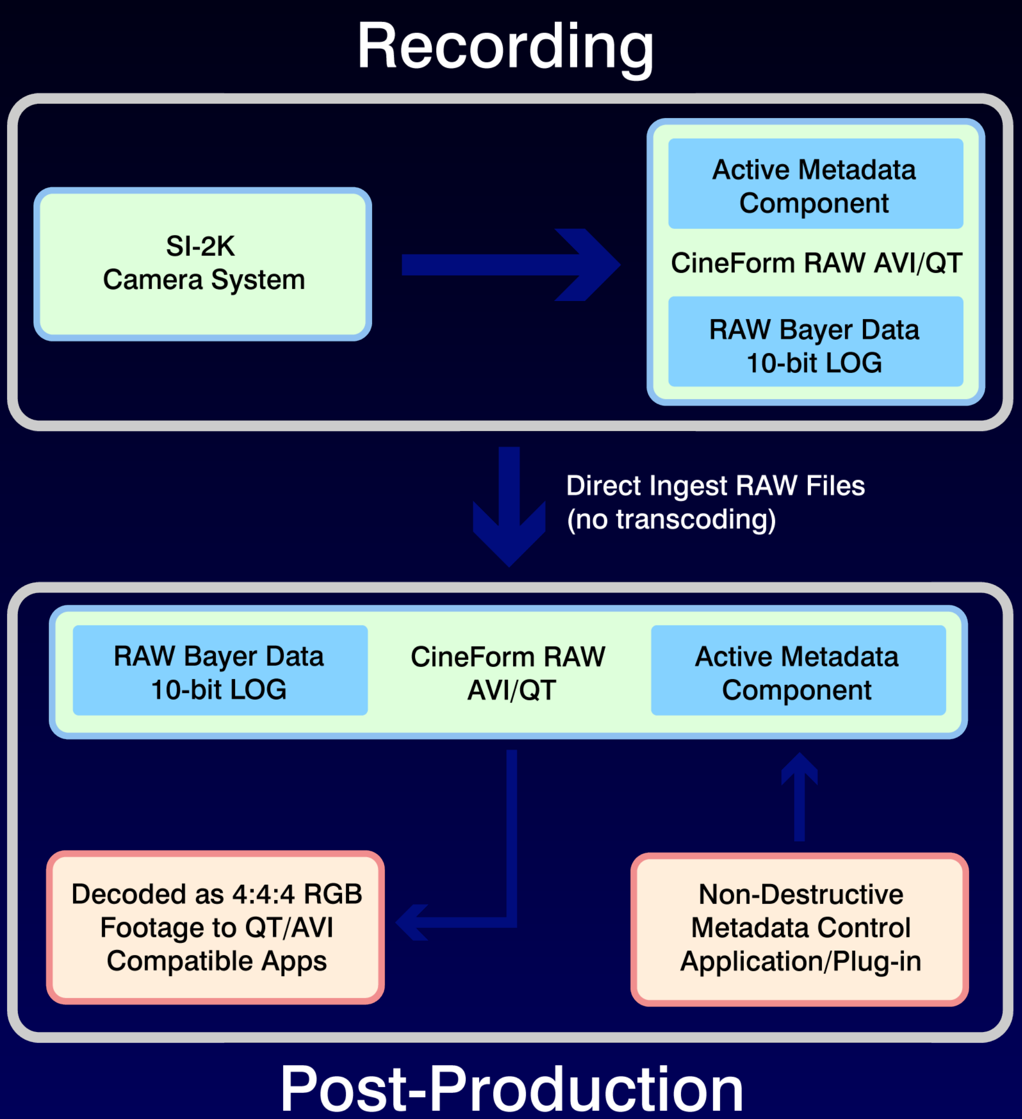
CineForm RAW™

- Solves a number of issues within the RAW workflow paradigms demonstrated:
  - Codec-level support of RAW, so files are directly editable after recording
  - Metadata-rich codec structure with hooks into host applications (Active Metadata™)
  - Uses the ability of wavelets to dynamically decode on-the-fly in either a real-time half-resolution mode or switch to full-resolution rendering for final output
  - Up to 4x 2K streams in real-time on a dual-Woodcrest workstation
  - 10-bit & 3.5:1 compression . . . wavelets are near mathematically lossless at this compression ratio

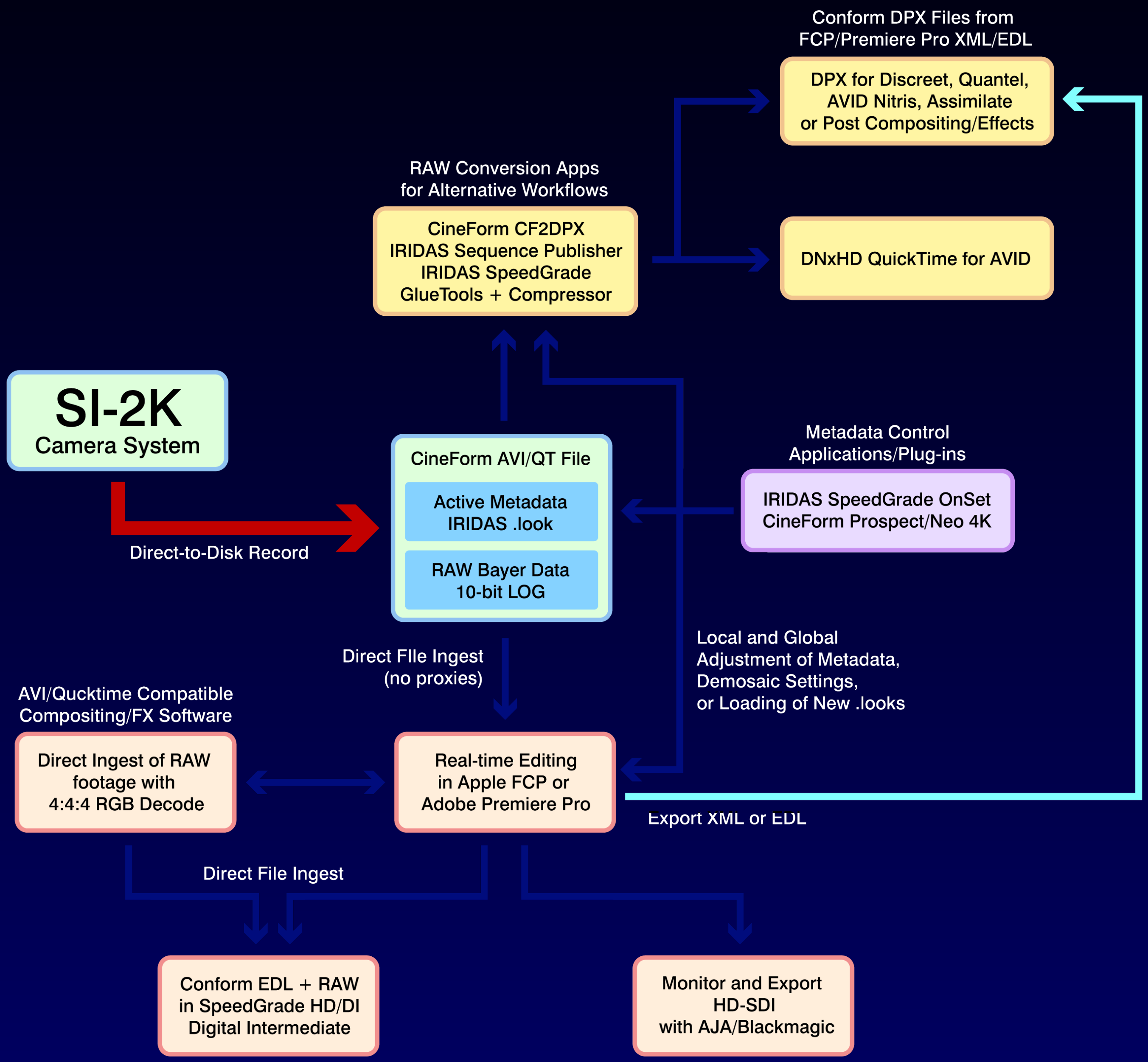
CineForm RAW™

- Further Key Features:
  - 32-bit floating point render engine at the codec level allows for metadata to virtually “clip” data, yet still maintain the RAW source underneath and pass that information to the host program
  - Embedded color management using IRIDAS .look format (floating point 3D LUT's)
    - Enables the ability to apply not only the end “look” non-destructively, but also apply gamut mapping for target color-spaces like film-prints, etc.
  - Codec-level metadata means that file-management is simpler . . . all metadata is in movie file wrapper

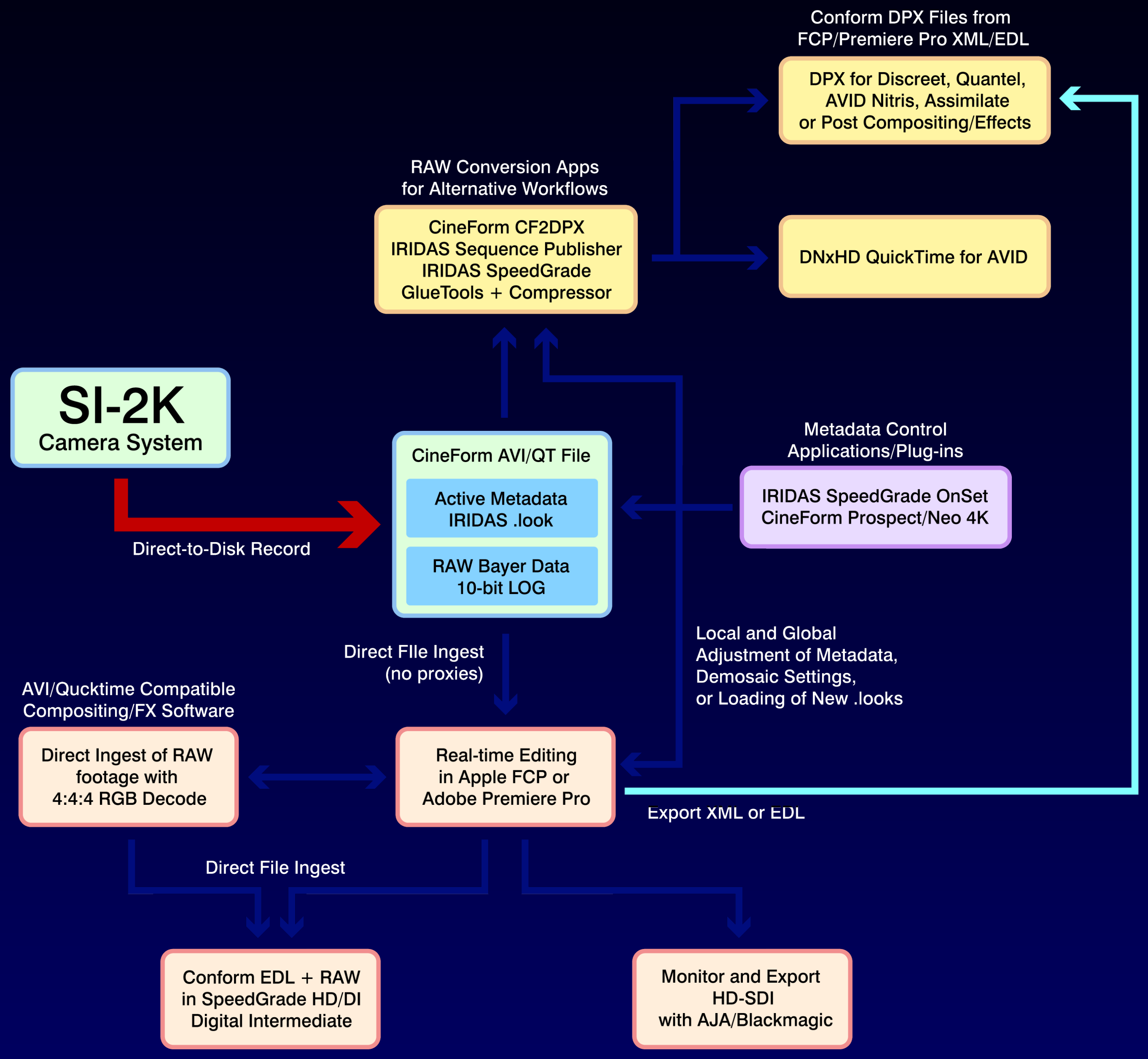
CineForm RAW™



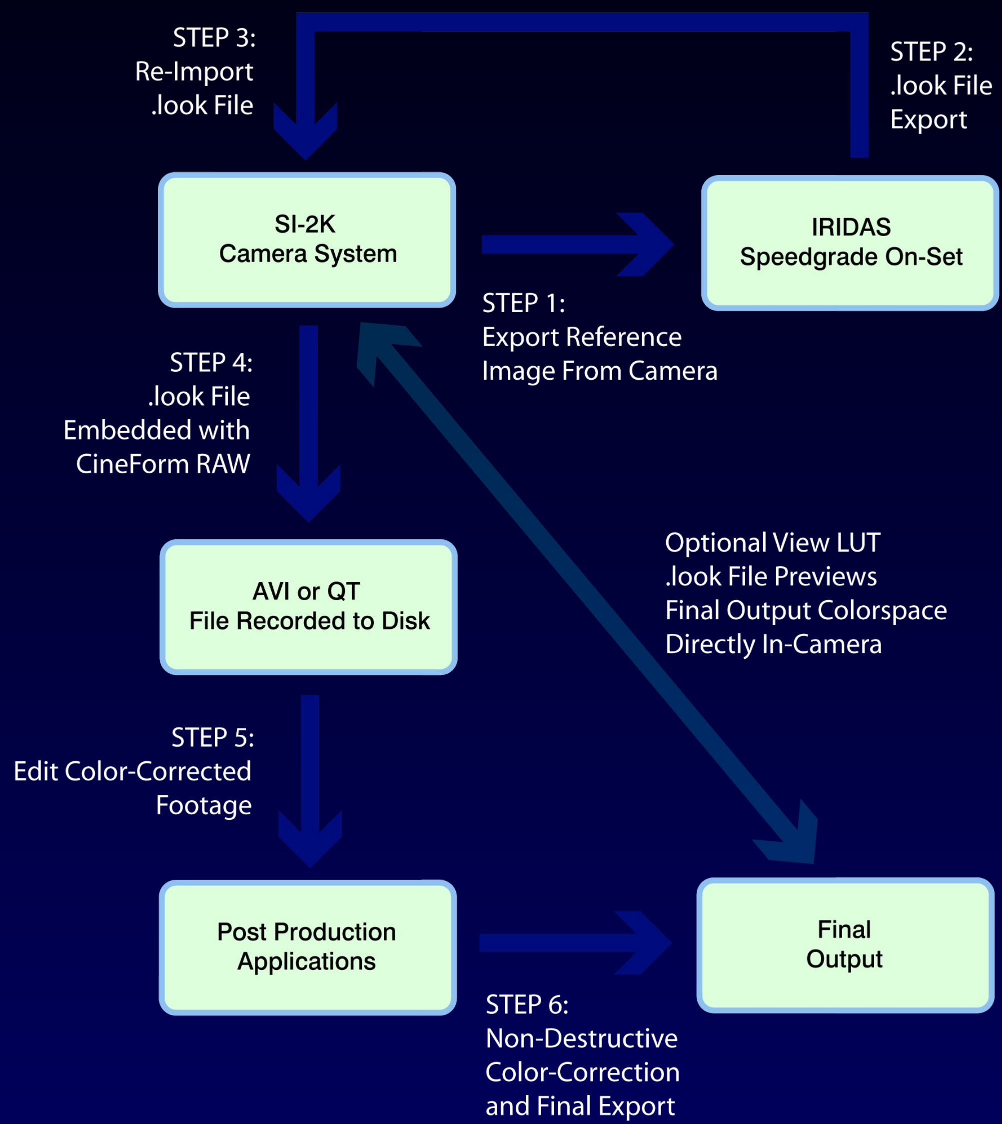
End-to-End Workflow



End-to-End Workflow



IRIDAS Color-Management



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