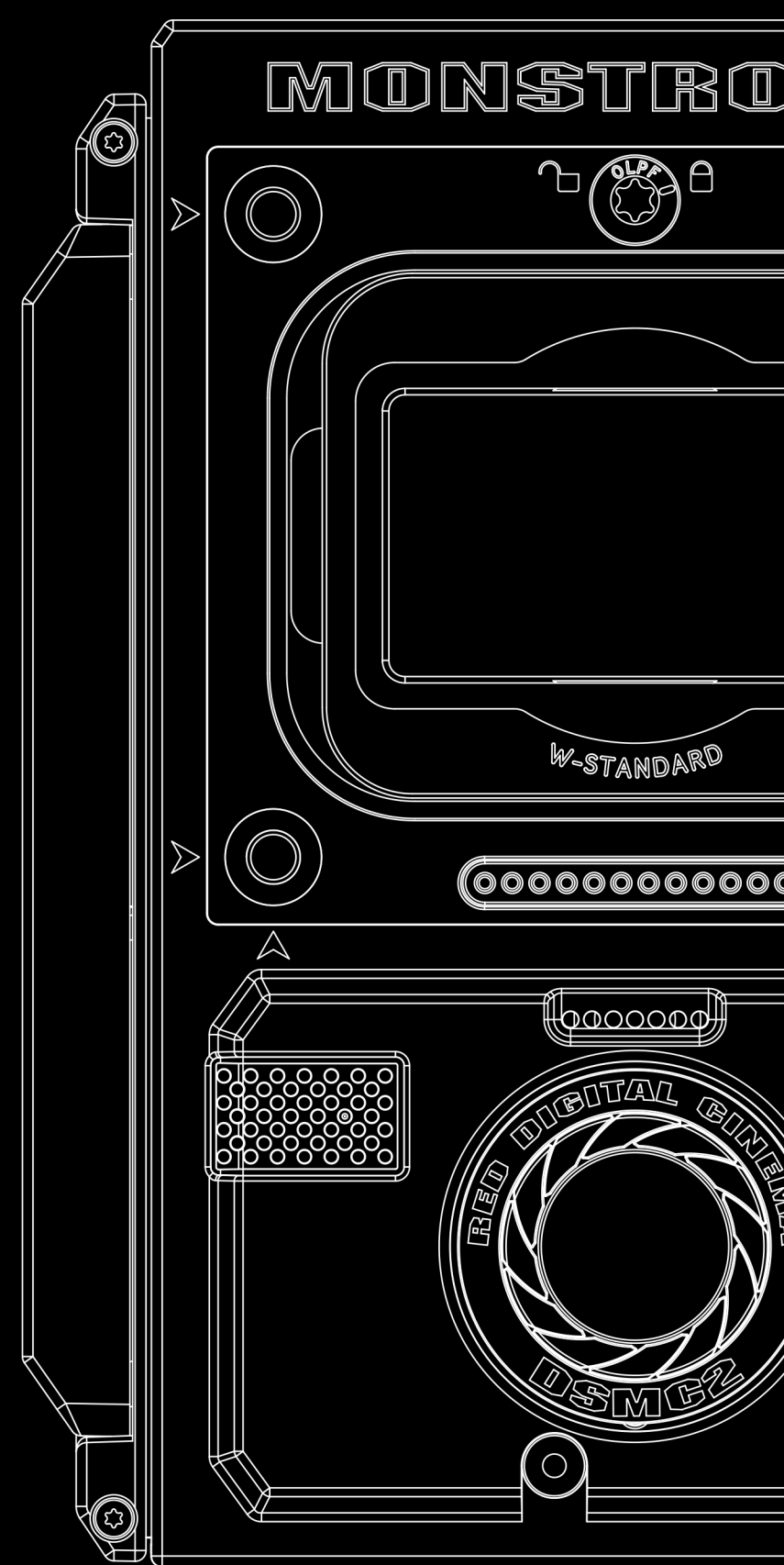


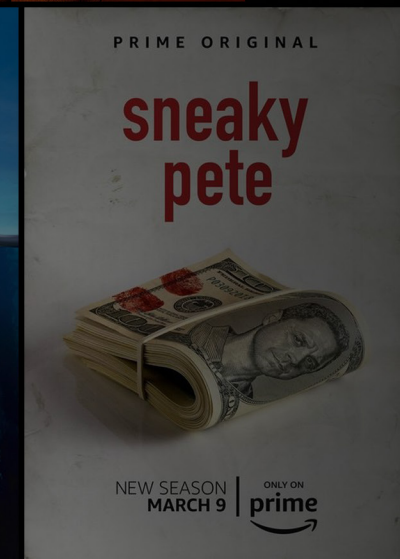
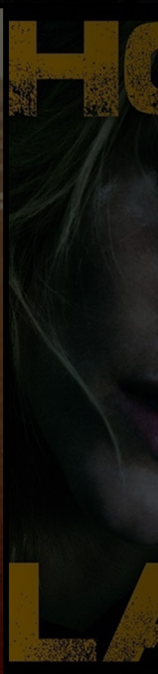
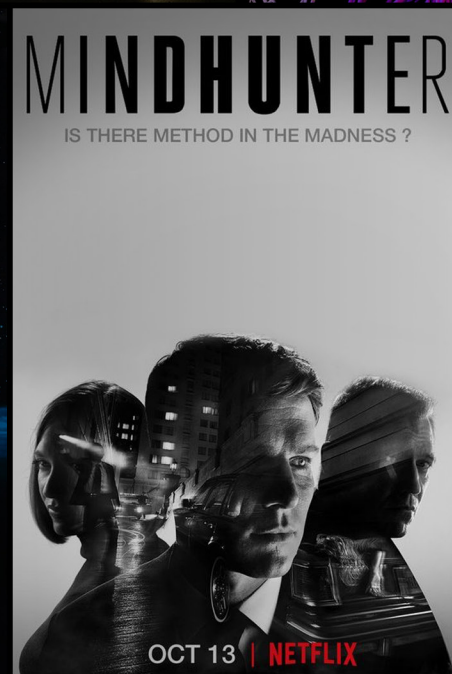
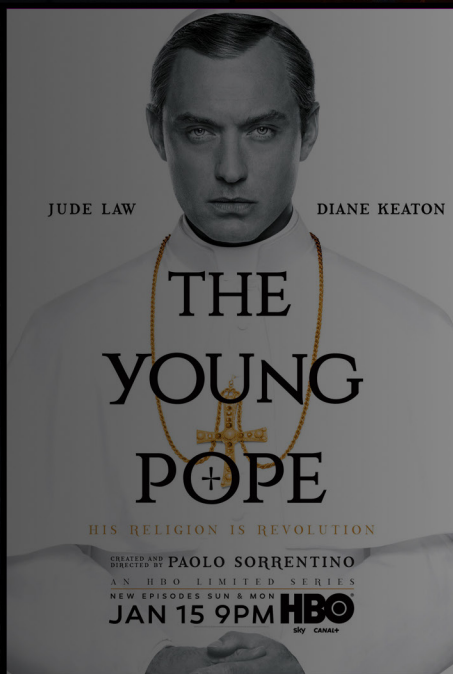
RED DIGITAL CINEMA

REAL-TIME 8K WORKFLOW | RED R3D SDK



ABOUT RED

RED



EVOLUTION OF RED

- Jim Jannard founded the company, and has had a lifelong interest in imagery. RED is his brainchild.
- RED is a technology company (both sensor and camera technology). RED is committed to obsolescence obsolete, by way of loyalty programs.
- Sensor Timeline
MYSTERIUM > MYSTERIUM-X > DRAGON >
DRAGON VV > HELIUM > MONSTRO VV > GEMINI
- Evolution of Brains
DSMC > DSMC2
- RED is committed to the DSMC2 through 2020, securing customers investment in products.



**REAL-TIME HIGH RESOLUTION
WORKFLOW IS NOW A REALITY**



REAL-TIME 8K WORKFLOW WITH R3D SDK

WHAT WE'LL BE COVERING

- The goal: to achieve playback of 8K footage at 24 FPS
- How big is an 8K frame?
- REDCODE RAW compression format
- The three stages of decompressing a frame
- Then there's demosaic
- How much work can we move to the GPU?
- How do we schedule it?
- What about rendering?
- Eureka! 24 FPS on a 2080
- So, how do you use it?
- REDCINE-X: RED's free editing software
- REDLINE: Command-line transcoding tool
- Who else uses it?

REAL-TIME 8K WORKFLOW WITH R3D SDK

THE GOAL: TO ACHIEVE PLAYBACK OF 8K FOOTAGE AT 24 FPS

- Most camera footage is shot at 23.976 FPS
- Our goal was to play 8K footage in real time on a single GPU



RED

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HOW BIG IS AN 8K FRAME?

- An 8K FF frame is 8192 pixels wide by 4320 pixels high
- That's 35,389,440 pixels in a single frame
- Each pixel is 4 bytes wide
- That's 141,557,760 bytes of data for each frame
- If we're outputting to 8-bit BGRA then that's another 141,557,760 bytes
- At 24 FPS that's 3,397,386,204 bytes of data to move each second
- How do we move that much data? **Compression**

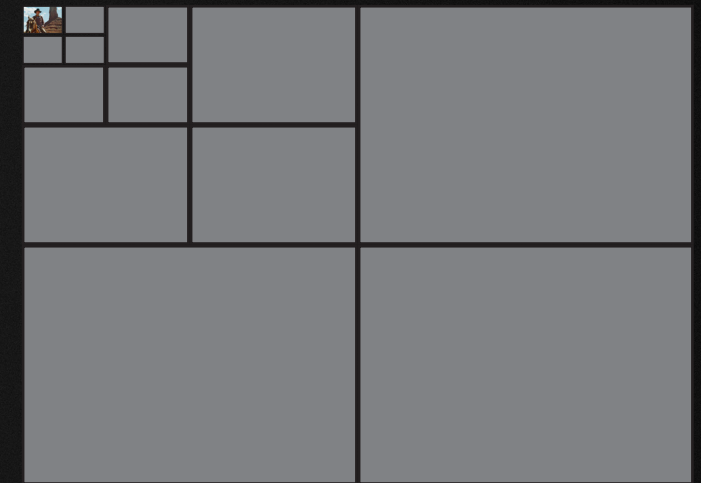


141,557,760 bytes/frame
3,397,386,204 bytes/second

REAL-TIME 8K WORKFLOW WITH R3D SDK

REDCODE RAW COMPRESSION FORMAT

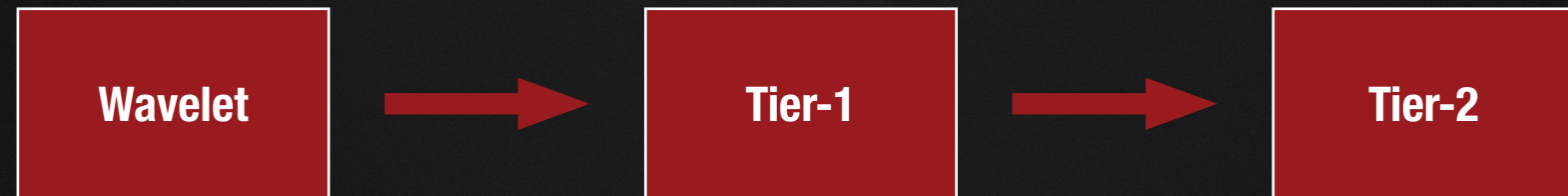
- Wavelet compression
- Smaller resolutions can be easily extracted and decoded (processing decreases by 75% per resolution removed)
- 16-bit pixels (DCT algorithms typically handle 8 or 10-bit pixels)



REAL-TIME 8K WORKFLOW WITH R3D SDK

THE THREE STAGES OF DECOMPRESSING A FRAME

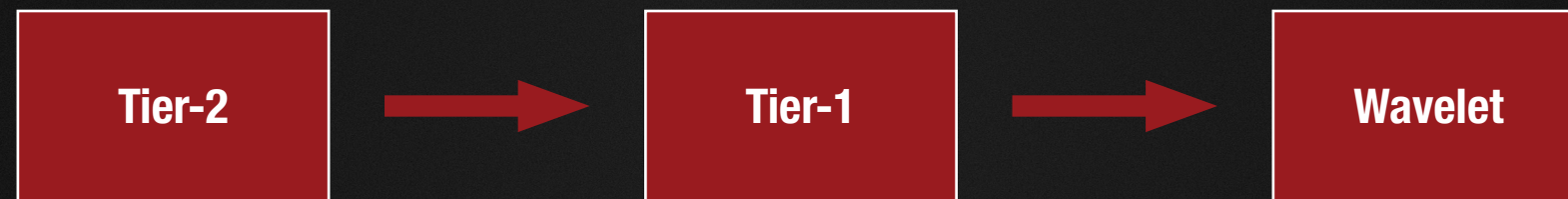
- REDCODE RAW is a proprietary wavelet compression codec.
- REDCODE RAW involves three stages of compression:
 - Wavelet transform - separate the image into approximation and detail coefficients
 - Tier 1 - block encode the wavelet coefficients using an entropy encoder
 - Tier 2 - encode the blocks into a bit stream



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THE THREE STAGES OF DECOMPRESSING A FRAME

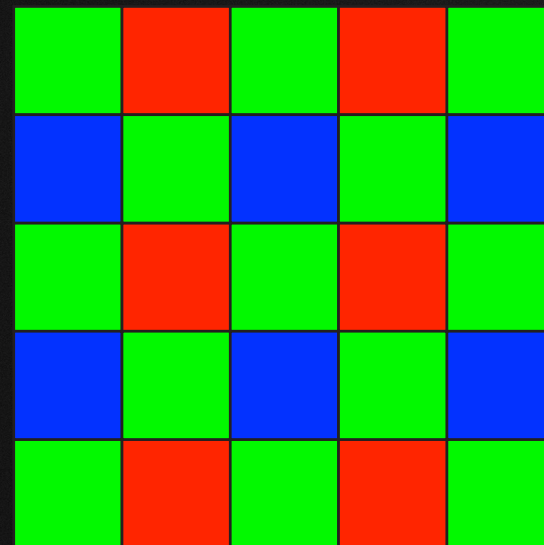
- To decompress the image we run the three stages in reverse



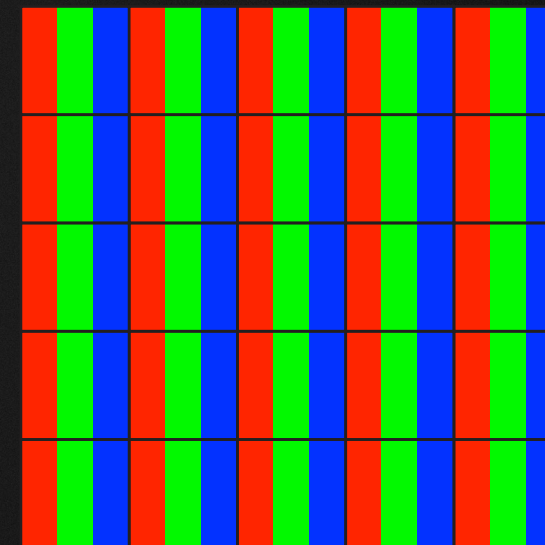
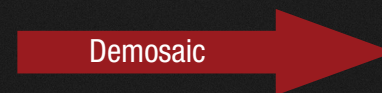
REAL-TIME 8K WORKFLOW WITH R3D SDK

THEN THERE'S DEMOSAIC

- The raw image is in the form of a Bayer array.
- Demosaicing is the process of converting the raw Bayer data into an RGB image of the same resolution.



Bayer pattern array



Resulting RGB image

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HOW MUCH WORK CAN WE MOVE TO THE GPU?

- **Tier-2 decode**
 - Stream based encoding, it can't be partitioned
 - Has to run on the CPU
- **Tier-1 decode**
 - Block based, it can be partitioned
 - Can be run on the GPU
- **Inverse wavelet transform**
 - Straightforward to implement on the GPU
- **Demosaic**
 - Already implemented on the GPU

REAL-TIME 8K WORKFLOW WITH R3D SDK

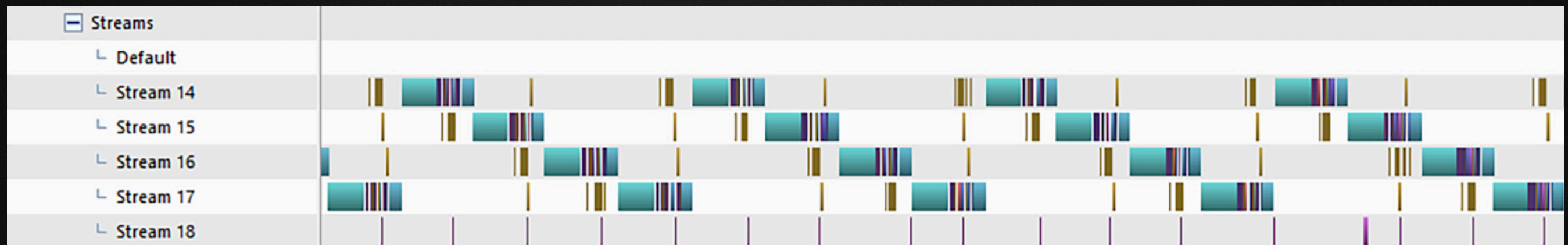
HOW MUCH WORK CAN WE MOVE TO THE GPU?

- **Challenges**
 - The Tier-2 decode produces a large amount of data that we need to move to the GPU.
 - The Tier-1 decode is computationally demanding - it contains a large number of loops and conditional blocks that are not optimal for GPU processing.
 - High divergence
 - Low occupancy
 - Even though we already had an implementation of demosaic on the GPU, we had to look for ways we could optimize it.

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HOW DO WE SCHEDULE IT?

- Overlap the Tier-2 decode on the CPU with the Tier-1 decode on the GPU
- Run multiple CUDA streams to fully saturate the GPU
 - Four streams seems to be the optimal number



Trace of decode & demosaic pipeline

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WHAT ABOUT RENDERING?

- We use OpenGL to render the frames to the screen.
- CUDA/OpenGL interop allows us to move the frame directly from CUDA memory to an OpenGL texture.
 - `cudaGraphicsMapResources()`
 - `cudaGraphicsRegisterImage()`
- We need to synchronize OpenGL with the decode kernels.

REAL-TIME 8K WORKFLOW WITH R3D SDK

EUREKA! 24+ FPS ON A 2080.

- Benefits
 - 8K real-time 24 fps or greater playback performance.
 - Up to 10x faster transcoding depending on the format and content.
 - Improved efficiencies and better quality control within the content review process.
 - Creative freedom using flexible RAW R3D files, rather than semi-baked proxy files

REAL-TIME 8K WORKFLOW WITH R3D SDK

SO, HOW DO YOU USE IT?

- Fully asynchronous API

```
Status status = RED_CUDA->processAsync(CUDA_DEVICE_ID, stream, cudaJob, err);  
cudaJob->completeAsync();
```

- Use multiple CUDA streams

REAL-TIME 8K WORKFLOW WITH R3D SDK

SO, HOW DO YOU USE IT?

- Memory management - provide your own memory manager

```
R3DSDK::EXT_CUDA_API api;  
api.cudaFree = SimpleMemoryPool::cudaFree;  
api.cudaFreeArray = SimpleMemoryPool::cudaFreeArray;  
api.cudaFreeHost = SimpleMemoryPool::cudaFreeHost;  
api.cudaHostAlloc = SimpleMemoryPool::cudaHostAlloc;  
api.cudaMalloc = SimpleMemoryPool::cudaMalloc;  
api.cudaMallocArray = SimpleMemoryPool::cudaMallocArray;  
api.cudaMallocHost = SimpleMemoryPool::cudaMallocHost;  
  
//CREATE THE REDCuda CLASS  
return new R3DSDK::REDCuda(api) ;
```


REAL-TIME 8K WORKFLOW WITH R3D SDK

REDCINE-X PRO: RED'S FREE EDITING SOFTWARE

- Available on Windows
- Supports projects and timelines
- Supports color grading
- Supports transcoding to many different formats
- Decode acceleration not available on Mac

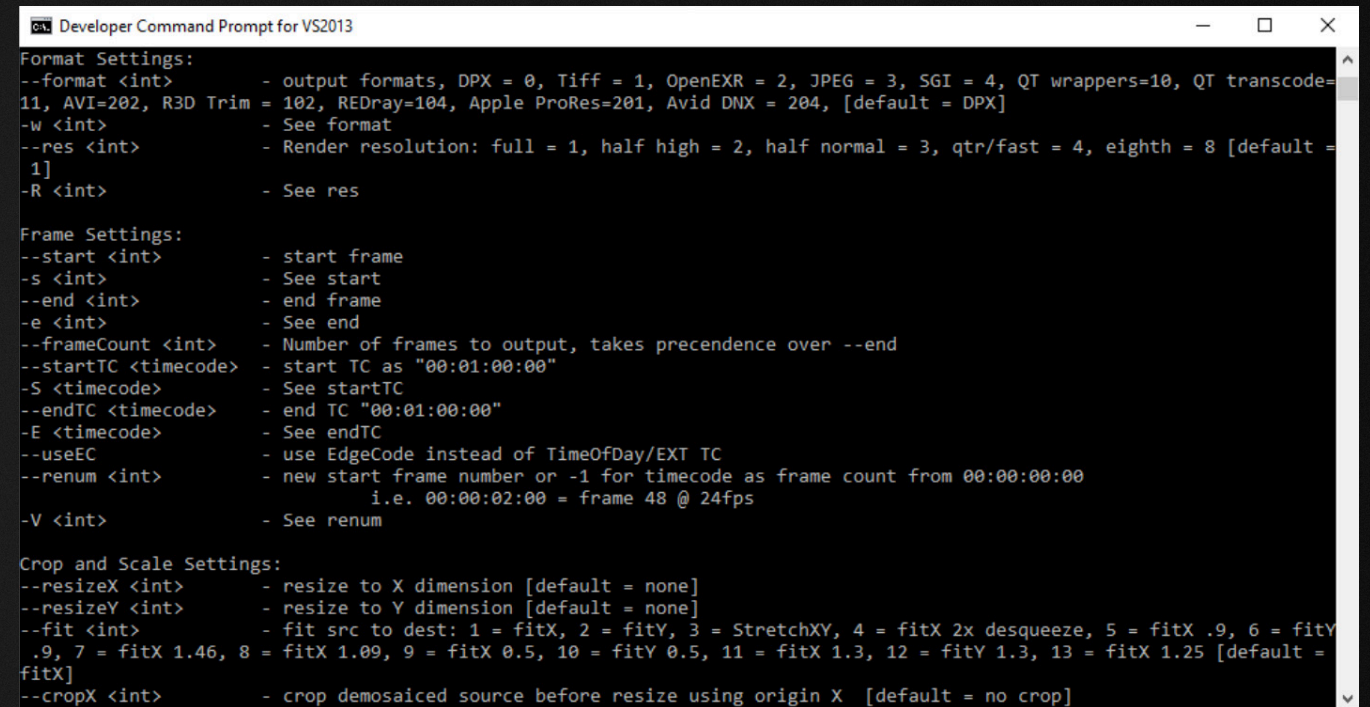


RED

REAL-TIME 8K WORKFLOW WITH R3D SDK

REDLINE: RED'S FREE COMMAND LINE TRANSCODE UTILITY

- Available on:
 - Windows
 - Linux
 - Mac (decode acceleration not available on Mac)
- Able to transcode to:
 - Apple ProRes
 - H.264
 - Mpeg
 - H.263
 - AVID DNX
 - AVI



```
Developer Command Prompt for VS2013

Format Settings:
--format <int>      - output formats, DPX = 0, Tiff = 1, OpenEXR = 2, JPEG = 3, SGI = 4, QT wrappers=10, QT transcode=
11, AVI=202, R3D Trim = 102, REDray=104, Apple ProRes=201, Avid DNX = 204, [default = DPX]
-w <int>            - See format
--res <int>         - Render resolution: full = 1, half high = 2, half normal = 3, qtr/fast = 4, eighth = 8 [default =
1]
-R <int>            - See res

Frame Settings:
--start <int>        - start frame
-s <int>             - See start
--end <int>          - end frame
-e <int>             - See end
--frameCount <int>   - Number of frames to output, takes precedence over --end
--startTC <timecode> - start TC as "00:01:00:00"
-S <timecode>        - See startTC
--endTC <timecode>   - end TC "00:01:00:00"
-E <timecode>        - See endTC
--useEC              - use EdgeCode instead of TimeOfDay/EXT TC
--renum <int>        - new start frame number or -1 for timecode as frame count from 00:00:00:00
                      i.e. 00:00:02:00 = frame 48 @ 24fps
-V <int>             - See renum

Crop and Scale Settings:
--resizeX <int>      - resize to X dimension [default = none]
--resizeY <int>      - resize to Y dimension [default = none]
--fit <int>          - fit src to dest: 1 = fitX, 2 = fitY, 3 = StretchXY, 4 = fitX 2x desqueeze, 5 = fitX .9, 6 = fitY
.9, 7 = fitX 1.46, 8 = fitX 1.09, 9 = fitX 0.5, 10 = fitY 0.5, 11 = fitX 1.3, 12 = fitY 1.3, 13 = fitX 1.25 [default =
fitX]
--cropX <int>        - crop demosaiced source before resize using origin X [default = no crop]
```


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WHO ELSE USES IT?

R3D SDK Integrators include:

- Adobe - Adobe Premiere Pro
- Blackmagic Design - DaVinci Resolve
- Apple - Final Cut Pro
- Autodesk - Flame
- AVID - Media Composer
- Colorfront - Transcoder
- Industrial Light & Magic
- Assimilate - Scratch
- Foundry - Nuke
- Baselight - Filmlight
- SGO - Mistika
- Fotokem

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QUESTIONS?