Preliminary Findings

HEVC: RATING THE CONTENDERS

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Agenda

- Who are the competitors?
- Performance tests
- Setting the ground rules
- Results
- Conclusions
- Left to do

Who Was Invited

- Companies asked to participate
  - Intel – distributing through OEMs only
  - Elemental – declined to participate
  - Ittiam – declined to participate – no bandwidth
  - Beamr/Vanguard – declined – bad timing
  - Vantrix – f.265 – no real effort behind technology
  - NTT – declined, primarily sell custom products to specific OEMs
  - MainConcept – yes!
  - X265 – publicly available – yes!

What I tested

- Codecs
  - x264 as baseline
  - Main Concept
  - X265
  - VP9
- Focus
  - VOD
  - Encoding time specific
  - 720p, 1080p, 4K
    - Five profiles each
  - Four video files
    - Netflix Meridian
    - Blender TOS
    - Blender Sintel
    - New test clip

Basic Encoding Parameters

720p	Codec	Width	Height	Data Rate	Bits/pixel (30 fps)	Max DR	VBV	Profile	Key-Frame	B-frame	Reference
500 kbps	**HEVC**	1280	720	500	0.0181	550	500	Main	2	3	6
1 mbps	**HEVC**	1280	720	1000	0.0362	1100	1000	Main	2	3	6
2 mbps	**HEVC**	1280	720	2000	0.0723	2200	2000	Main	2	3	6
3 mbps	**HEVC**	1280	720	3000	0.1085	3300	3000	Main	2	3	6
4 mbps	**HEVC**	1280	720	4000	0.1447	4400	4000	Main	2	3	6
1080p											
1 mbps	**HEVC**	1920	1080	1000	0.0161	1100	1000	Main	2	3	6
2 mbps	**HEVC**	1920	1080	2000	0.0322	2200	2000	Main	2	3	6
4 mbps	**HEVC**	1920	1080	4000	0.0643	4400	4000	Main	2	3	6
6 mbps	**HEVC**	1920	1080	6000	0.0965	6600	6000	Main	2	3	6
8 mbps	**HEVC**	1920	1080	8000	0.1286	8800	8000	Main	2	3	6
4K											
4 mbps	**HEVC**	3840	2160	4000	0.0161	4400	4000	Main	2	3	6
8 mbps	**HEVC**	3840	2160	8000	0.0322	8800	8000	Main	2	3	6
12 mbps	**HEVC**	3840	2160	16000	0.0643	17600	16000	Main	2	3	6
16 mbps	**HEVC**	3840	2160	24000	0.0965	26400	24000	Main	2	3	6
20 mbps	**HEVC**	3840	2160	32000	0.1286	35200	32000	Main	2	3	6

Data Rate to +/- 5%

	Sintel			Tears of Steel				New			Meridien	
	120	Actual	%	180	Actual	%	96	Actual	%	180	Actual	%
720p												
500	7,500	7,501	100.01%	11,250	11,341	100.81%	6,000	6,197	103.28%	11,250	10,000	88.89%
1000	15,000	14,677	97.85%	22,500	22,660	100.71%	12,000	12,024	100.20%	22,500	22,510	100.04%
2000	30,000	30,077	100.26%	45,000	45,625	101.39%	24,000	24,255	101.06%	45,000	45,016	100.04%
3000	45,000	45,243	100.54%	67,500	68,326	101.22%	36,000	36,264	100.73%	67,500	67,575	100.11%
4000	60,000	60,230	100.38%	90,000	94,279	104.75%	48,000	48,240	100.50%	90,000	90,153	100.17%

Encoding Details – x265

- Encoded in x265
- Simple command string created by x265 developers
-

```
x265 --input s:\New_720p.YUV --input-res 1280x720 --fps 29.97 --keyint 60 --min-keyint 60 --bframes 3 --ref 6 --bitrate 500 --vbv-maxrate 550 --vbv-bufsize 500 --preset slow --output h:\New_720p_29_1M.hevc --no-scenecut --tune psnr --pass 1 --slow-firstpass --stats T_720p_1M.log

x265 --input s:\New_720p.YUV --input-res 1280x720 --fps 29.97 --keyint 60 --min-keyint 60 --bframes 3 --ref 6 --bitrate 500 --vbv-maxrate 550 --vbv-bufsize 500 --preset slow --output h:\New_720p_29_1M.hevc --no-scenecut --tune psnr --pass 2 --stats T_720p_1M.log --csv %CSV%
```

Encoding Details – MainConcept

- Encoded with encoder SDK v.1
- Command string and ini files supplied by MainConcept
- Used SABET for encoding
  - Smart Adaptive Bitrate Encoding Technology.
  - Encode source into up to 12 HEVC videos with different resolution and bitrate in one encoding step
  - Primary benefit is encoding time saving with a very slight cost in quality
    - According to MC, my tests did not confirm

Encoding Details – x264

- Encoded in same version of FFmpeg
- Simple command string

```
ffmpeg -y -i New_720p.mp4 -c:v libx264 -preset veryslow -g 60 -keyint_min 60 -
sc_threshold 0  -bf 3 -refs 6 -b_strategy 2 -b:v 4000k -pass 1  -f mp4 NUL && \

ffmpeg -i New_720p.mp4 -c:v libx264 -preset veryslow -g 60 -keyint_min 60 -
sc_threshold 0  -bf 3 -refs 6  -b_strategy 2   -b:v 1000k -maxrate 1100k -bufsize 1000k -
pass 2  New_720p_1M.mp4

ffmpeg -i New_720p.mp4 -c:v libx264 -preset veryslow -g 60 -keyint_min 60 -
sc_threshold 0  -bf 3 -refs 6  -b_strategy 2   -b:v 2000k -maxrate 2200k -bufsize 2000k -
pass 2  New_720p_2M.mp4
```

Encoding Details – VP9

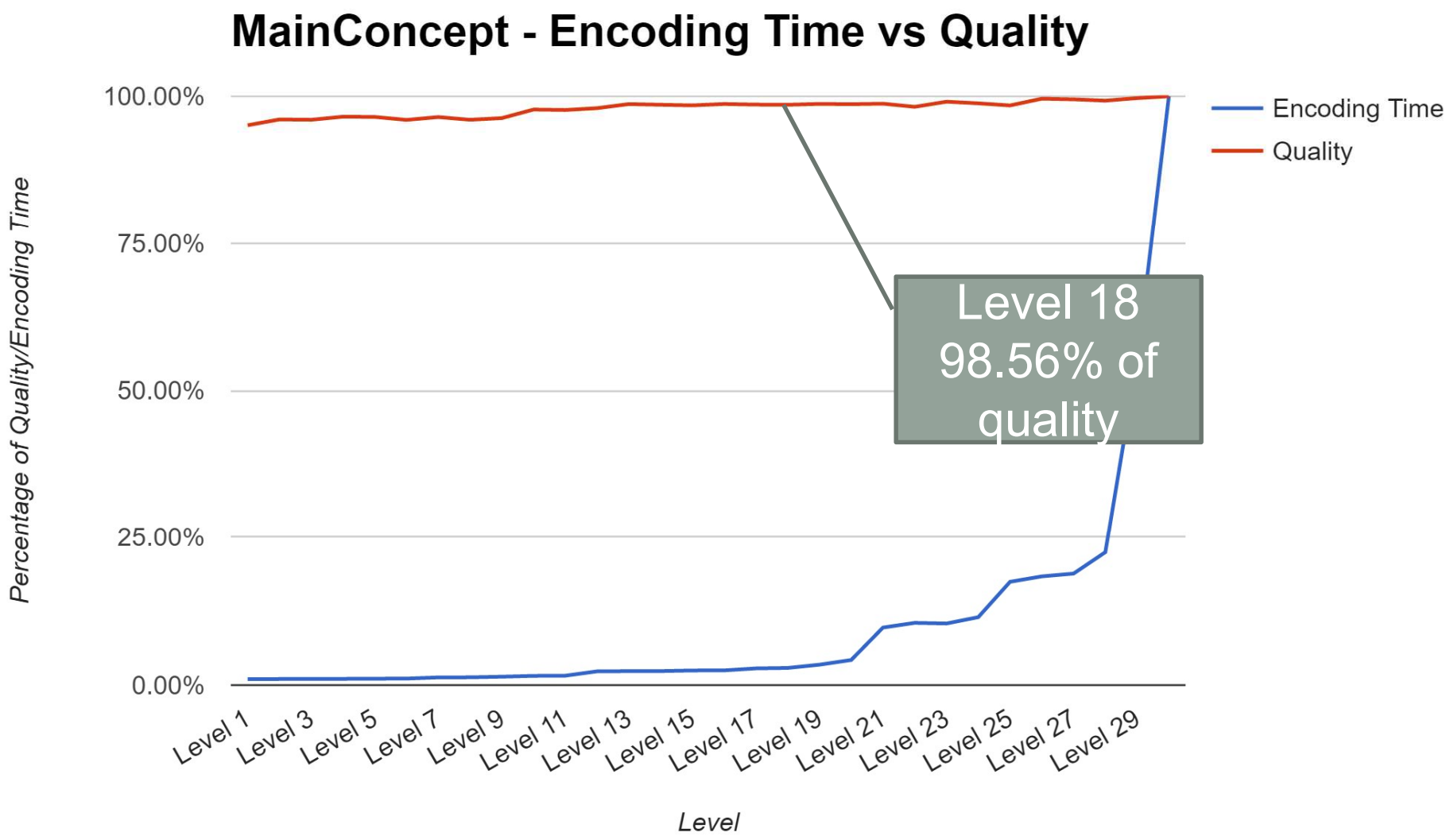
- Encoded in same version of FFmpeg
- Reviewed by Google for my last book, Video Encoding by the Numbers

```
ffmpeg -y -i sintel_720p.mp4 -c:v libvpx-vp9 -pass 1 -b:v 8000K -keyint_min 48 -g 48  -threads 8 -speed 1 -tile-columns 4 -frame-parallel 1  -f webm NUL && \

ffmpeg -i sintel_720p.mp4 -c:v libvpx-vp9 -pass 2 -b:v 4000K -keyint_min 48 -g 48  -threads 8 -speed 1 -tile-columns 4  -frame-parallel 1  -an -f webm sintel_720p_4M.webm

ffmpeg -i sintel_720p.mp4 -c:v libvpx-vp9 -pass 2 -b:v 3000K -keyint_min 48 -g 48  -threads 8 -speed 1 -tile-columns 4  -frame-parallel 1  -an -f webm sintel_720p_3M.webm
```

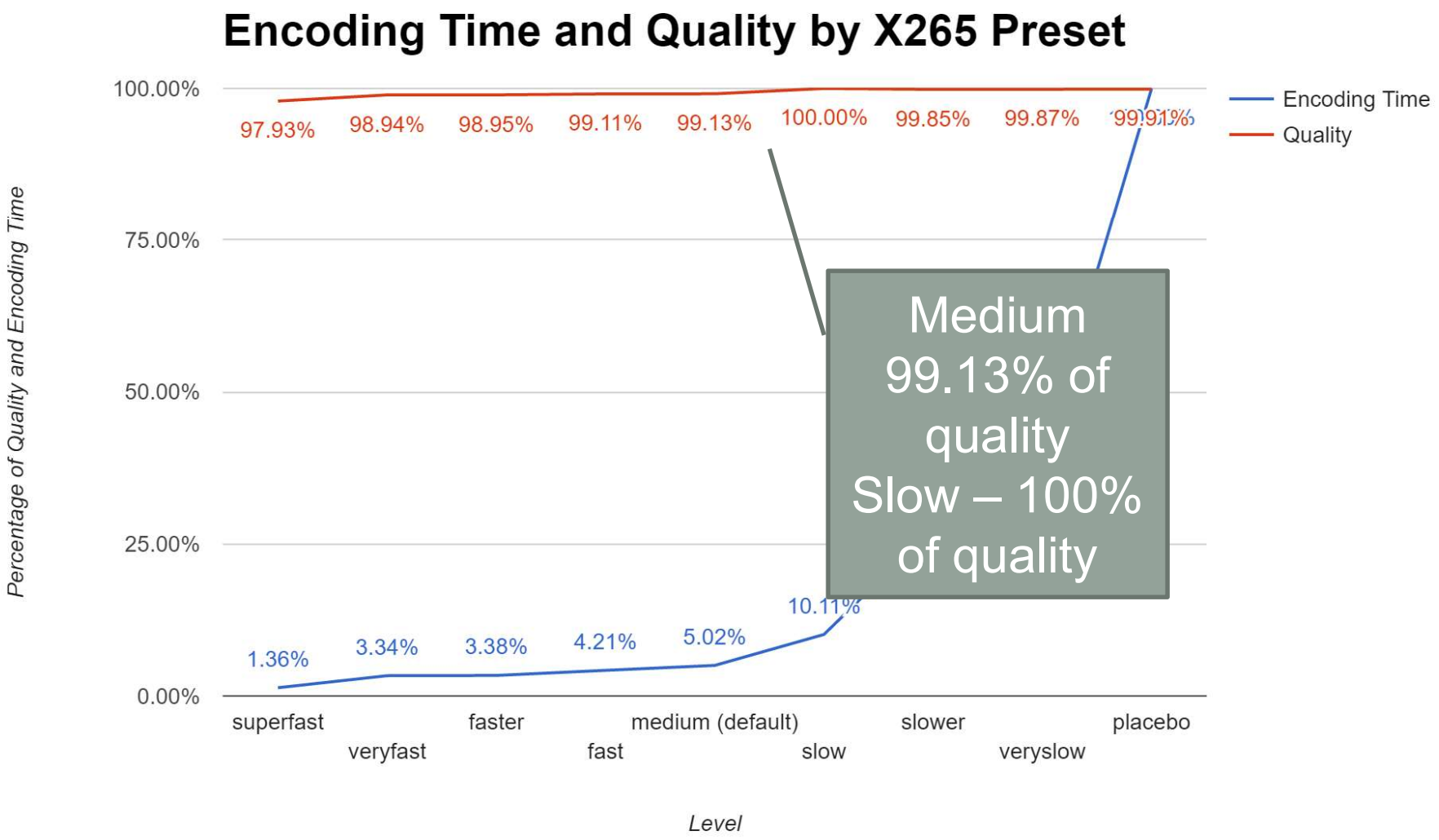
Choosing the Quality Setting

- Tried to find reasonable setting where MC/x265 performed similarly
- Performance tests
  - MainConcept – used SABET – Level 18
  - X265 – used Capella Systems Cambria Encoder
    - FFmpeg was serial, not parallel – Medium preset
  - VP9 – encoded five files in parallel, used that time
  - X264 – just used very slow preset which was much faster than all other tested technologies

MainConcept – Times and Quality



x265 – Times and Quality



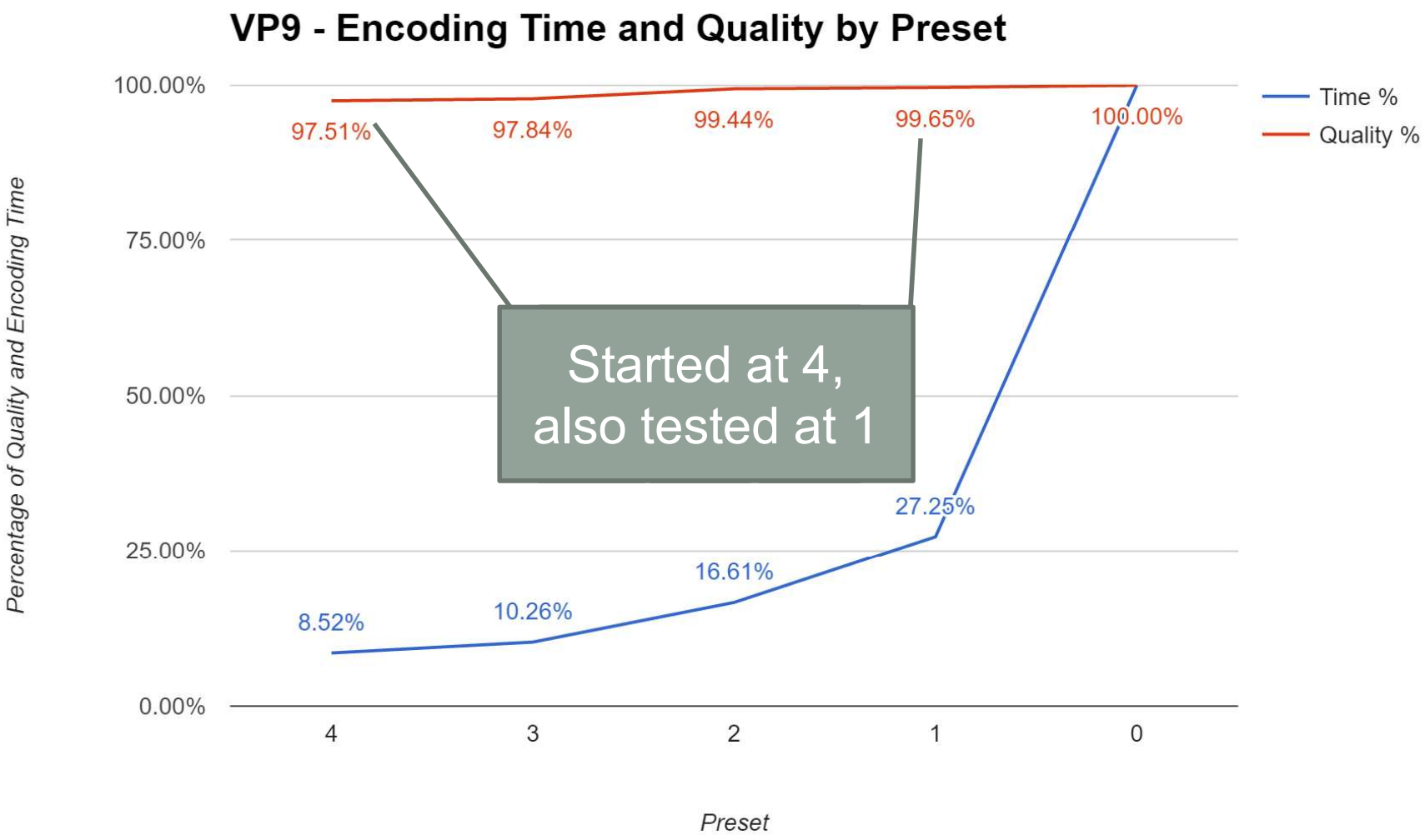
X265 Drama

- Original encodes without PSNR tuning
  - Sunday morning (after having encoding scripts for 12 days) For your results to be valid you need to use --tune psnr for PSNR comparisons, and --tune ssim for SSIM or SSIM plus comparisons.
  - There are several algorithm in x265 that we know for sure will hurt PSNR and SSIM scores, but we also know they improve subjective visual quality.
  - They’re on by default because people care about subjective visual quality and not PSNR or SSIM scores. But you can’t leave them on if you’re going to compare PSNR or SSIM... that would be totally invalid.

Decision

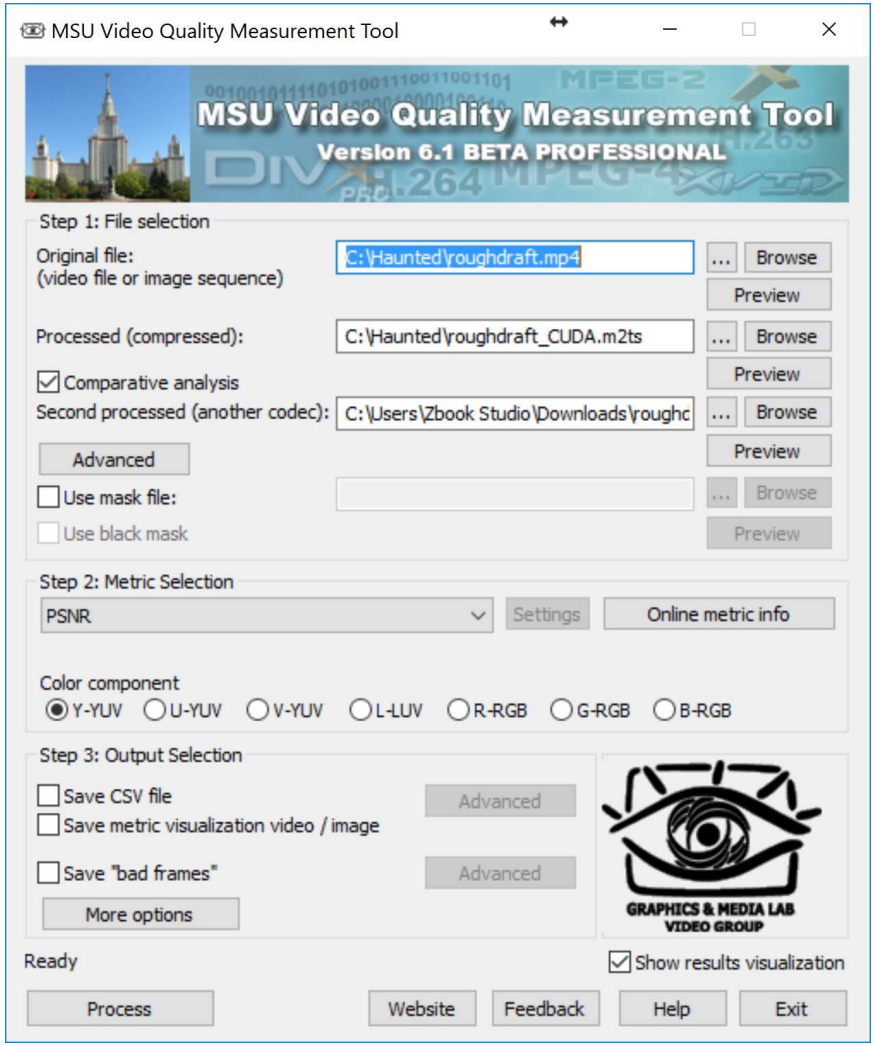
- X265 will reencode with PSNR tuning
- We will measure with MSU VQMT
- Problem: used Slow, not Medium
- Resolution: Adjusted numbers downward to 99.1% of quality
  - Not perfect, but best I could do
    - X265 results are with PSNR tuning enabled (+ 2-3% quality)
    - Adjusted by .991

VP9 – Times and Quality

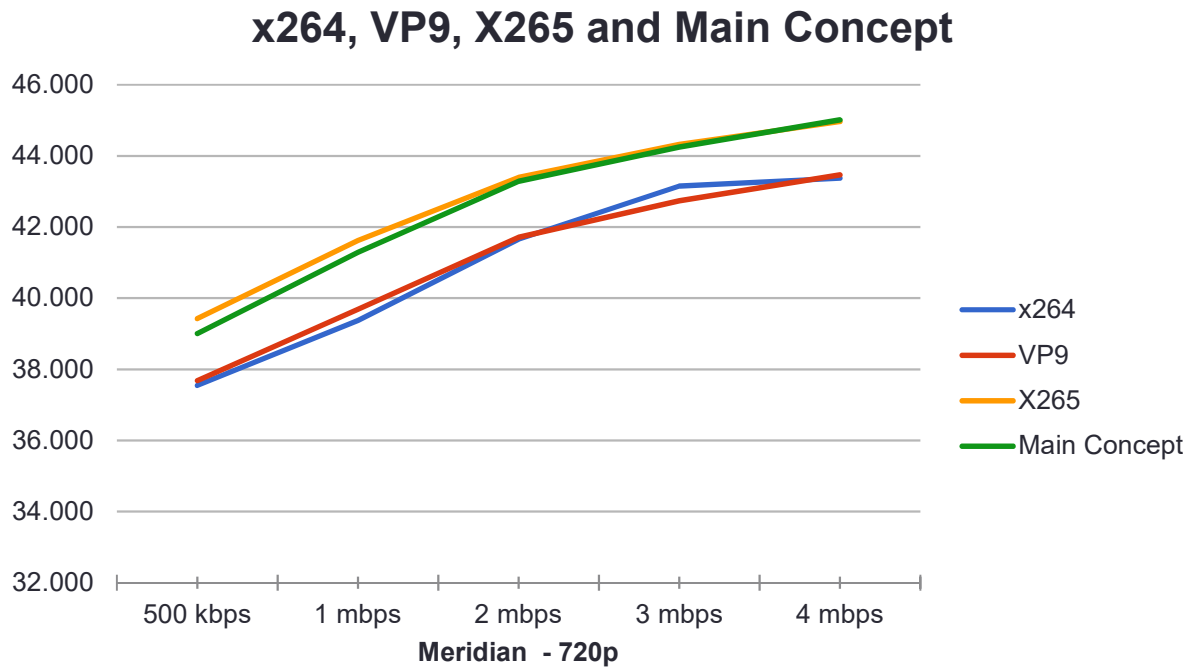


Measured Quality with VQMT

- PSNR

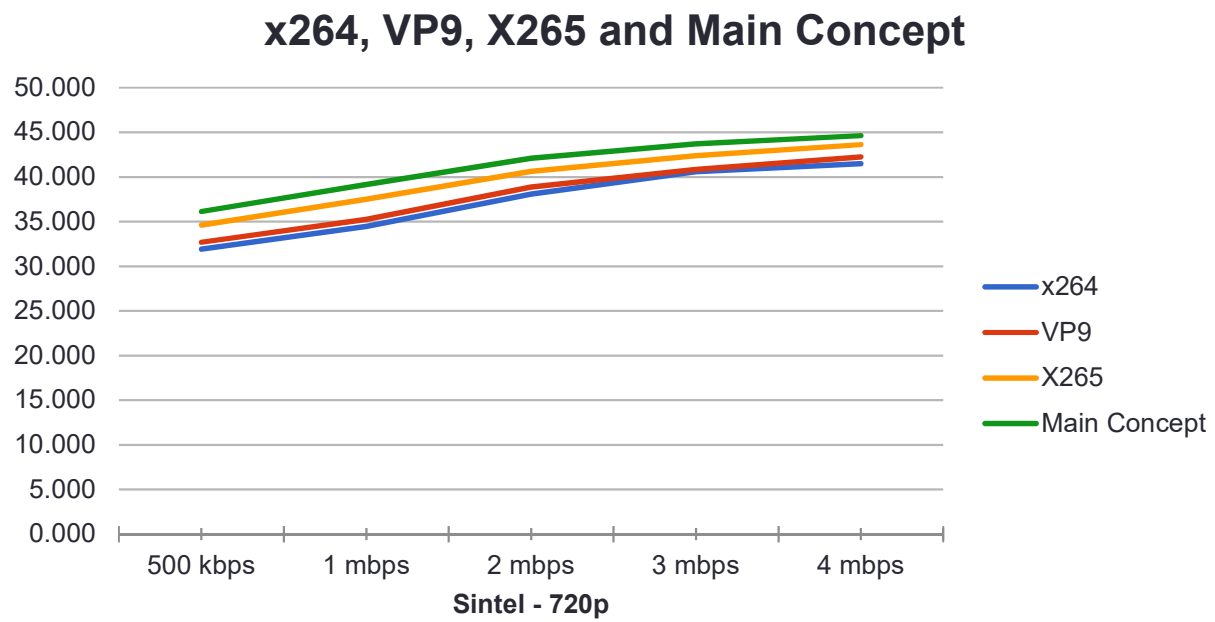


Meridian – 720p



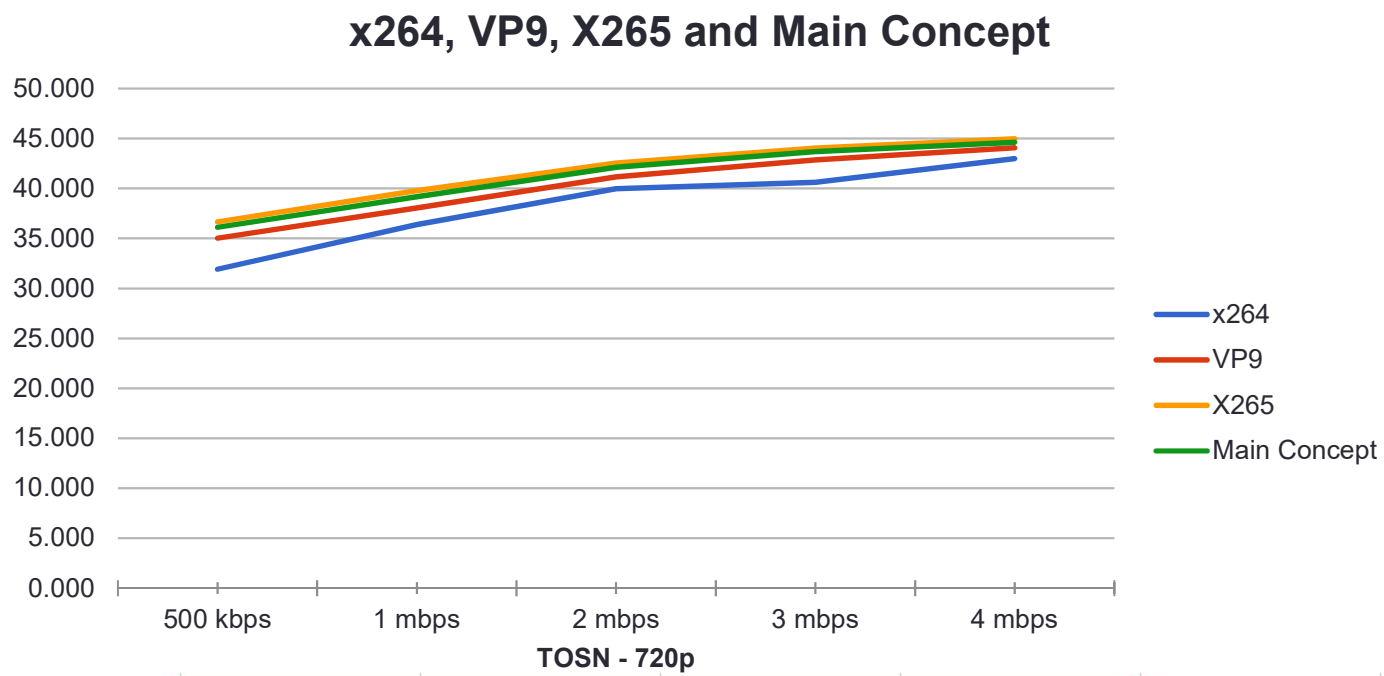
Meridian - 720p	x264	VP9	X265	Main Concept	Max Delta	MC/X265
500 kbps	37.546	37.680	39.424	39.007	5.00%	-1.07%
1 mbps	39.373	39.686	41.623	41.287	5.72%	-0.81%
2 mbps	41.654	41.717	43.390	43.289	4.17%	-0.24%
3 mbps	43.153	42.736	44.318	44.251	3.70%	-0.15%
4 mbps	43.372	43.467	44.962	45.011	3.78%	0.11%
Average	**41.020**	**41.057**	**42.743**	**42.569**	**4.20%**	**-0.41%**

Sintel – 720p



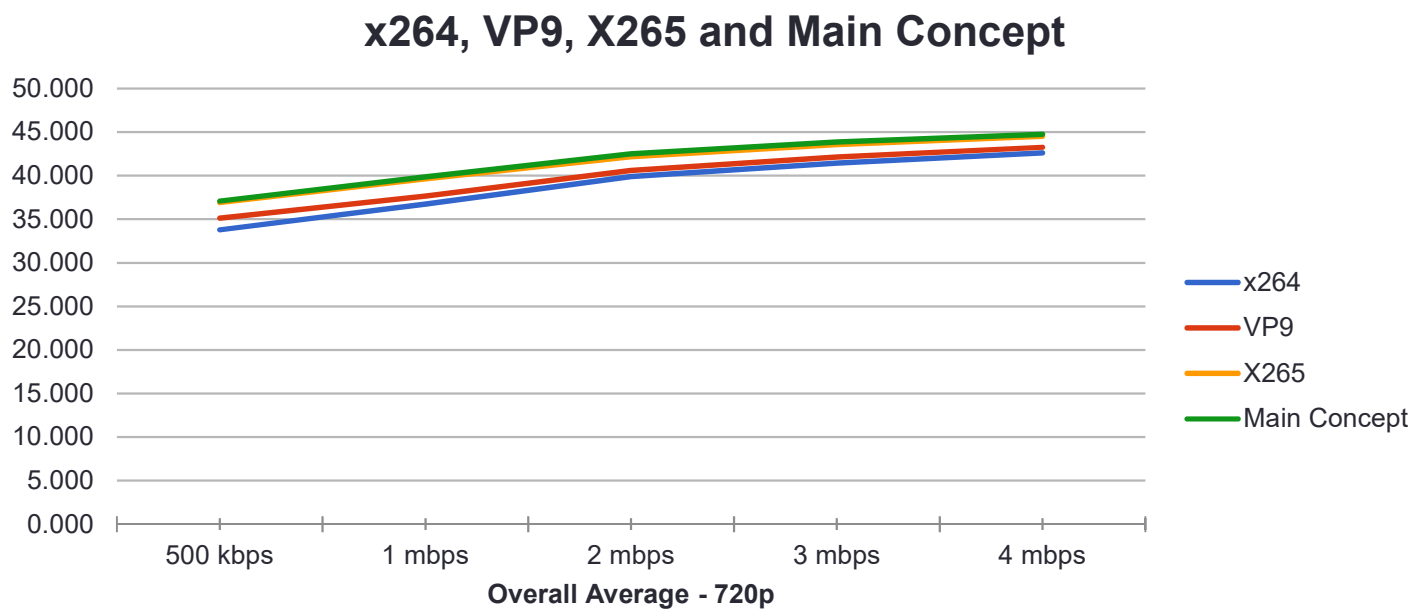
Sintel - 720p	x264	VP9	X265	Main Concept	Max Delta	MC/X265
500 kbps	31.918	32.697	34.614	36.126	13.18%	4.19%
1 mbps	34.466	35.240	37.521	39.180	13.68%	4.23%
2 mbps	38.087	38.860	40.617	42.109	10.56%	3.55%
3 mbps	40.606	40.840	42.394	43.701	7.62%	2.99%
4 mbps	41.492	42.243	43.627	44.629	7.56%	2.25%
Average	**37.314**	**37.976**	**39.754**	**41.149**	**10.28%**	**3.39%**

Tears of Steel – 720p



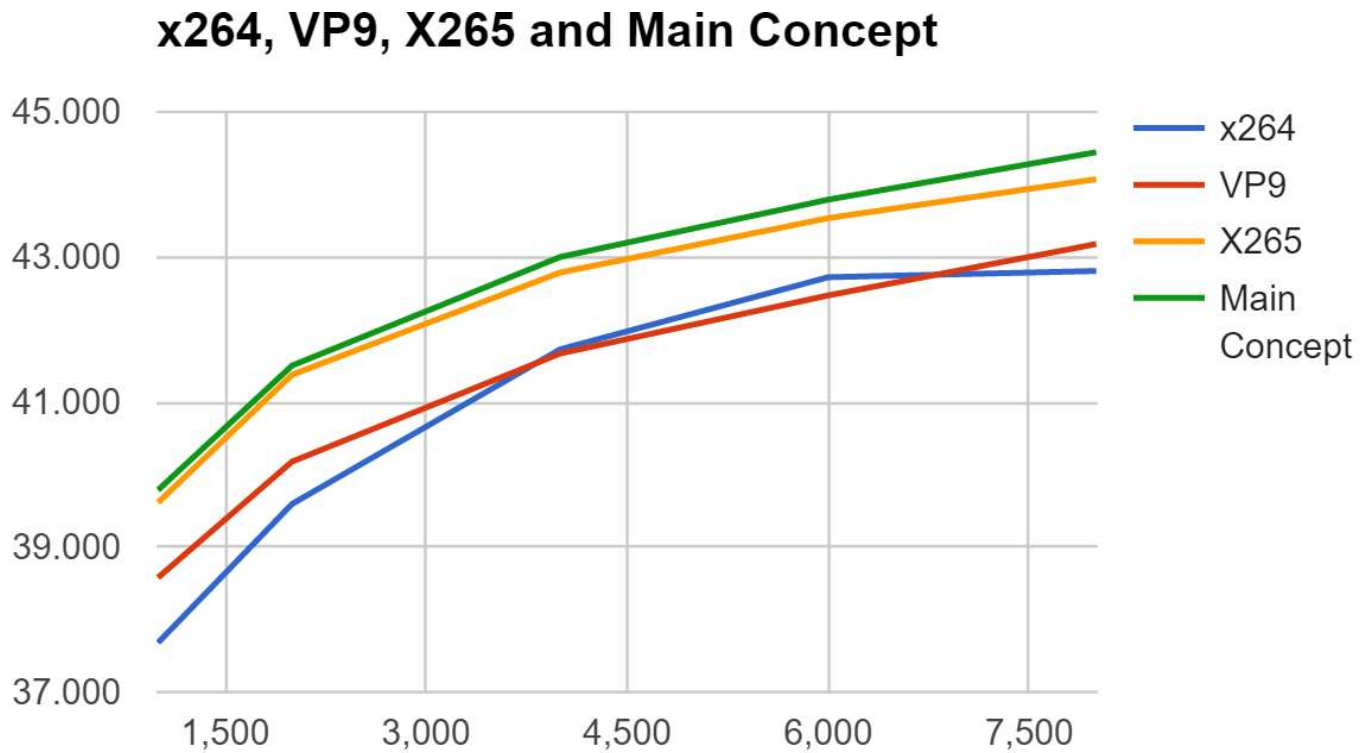
TOSN - 720p	x264	VP9	X265	Main Concept	Max Delta	MC/X265
500 kbps	31.918	35.030	36.666	36.126	14.88%	-1.49%
1 mbps	36.383	38.065	39.779	39.180	9.34%	-1.53%
2 mbps	39.964	41.178	42.554	42.109	6.48%	-1.06%
3 mbps	40.606	42.856	44.030	43.701	8.43%	-0.75%
4 mbps	42.991	44.070	44.982	44.629	4.63%	-0.79%
Average	**38.372**	**40.240**	**41.602**	**41.149**	**8.42%**	**-1.10%**

Overall – 720p



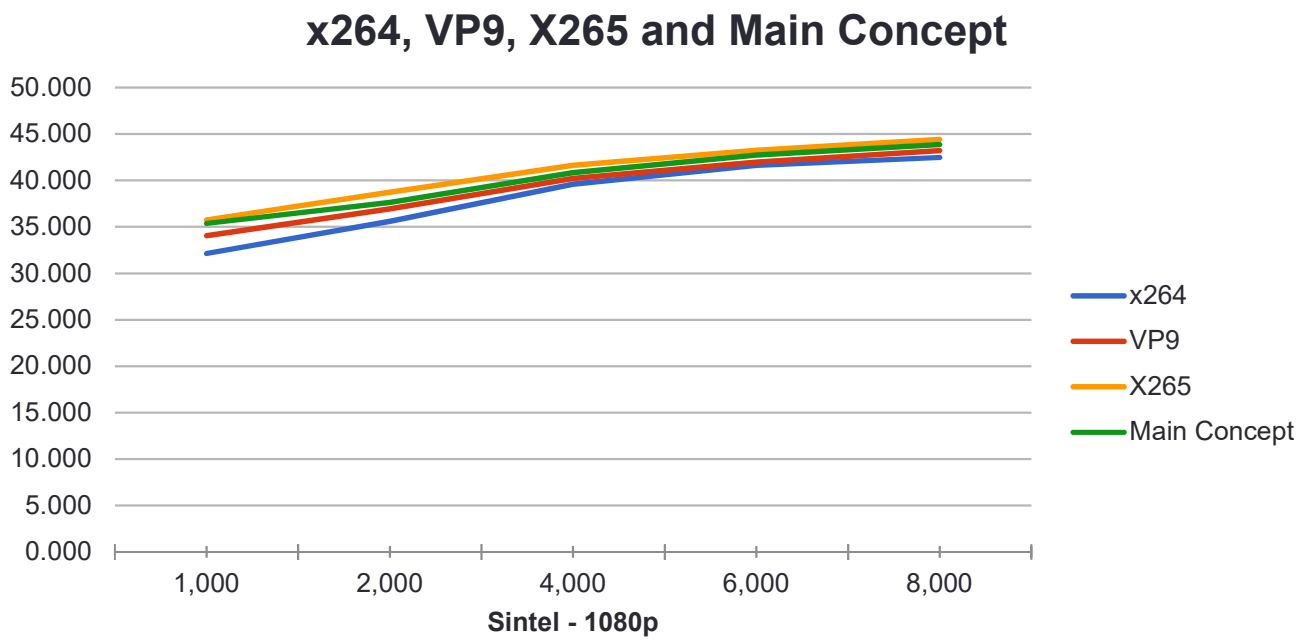
Overall - 720p	x264	VP9	X265	Main Concept	Max Delta	MC/X265
500 kbps	33.794	35.135	36.901	37.086	9.74%	0.50%
1 mbps	36.740	37.664	39.641	39.882	8.55%	0.60%
2 mbps	39.901	40.585	42.187	42.502	6.52%	0.74%
3 mbps	41.455	42.144	43.581	43.884	5.86%	0.69%
4 mbps	42.619	43.260	44.523	44.756	5.02%	0.52%
Average	**38.902**	**39.758**	**41.367**	**41.622**	**6.99%**	**0.61%**

Meridian – 1080p



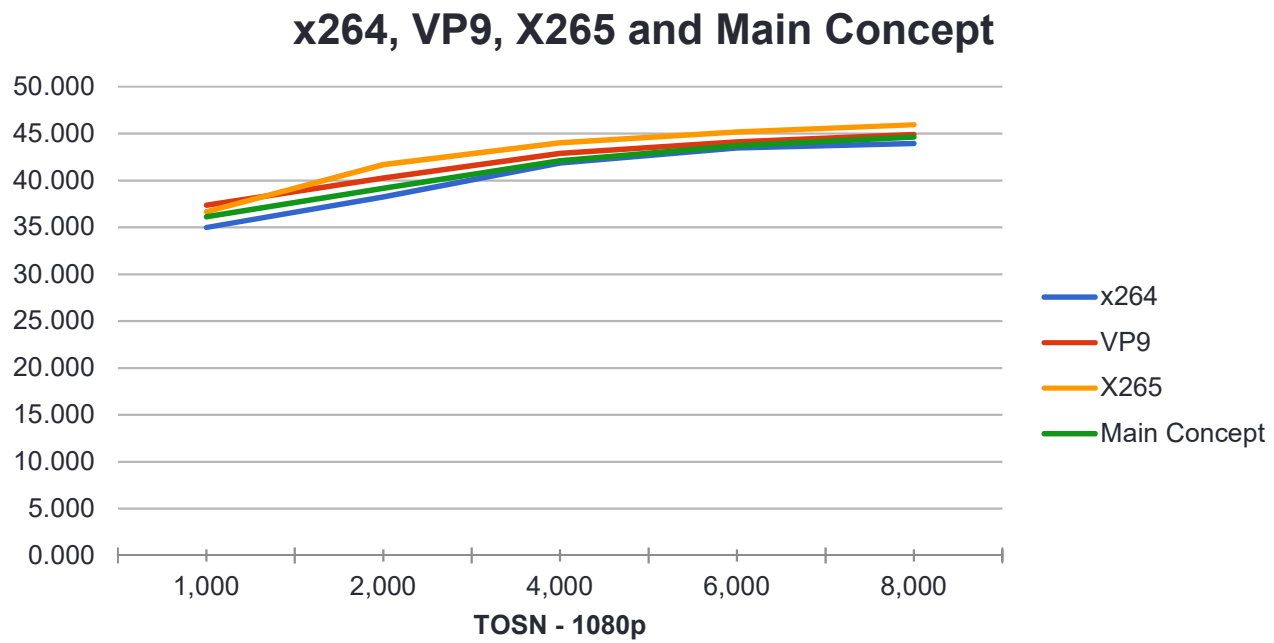
Meridian - 1080p	x264	VP9	X265	Main Concept	Max Delta	MC/X265
1,000	37.681	38.578	39.613	39.785	5.58%	0.43%
2,000	39.593	40.177	41.374	41.501	4.82%	0.31%
4,000	41.724	41.667	42.783	42.998	3.19%	0.50%
6,000	42.719	42.468	43.534	43.788	3.11%	0.58%
8,000	42.805	43.176	44.071	44.443	3.83%	0.84%
Average	**40.904**	**41.213**	**42.275**	**42.503**	**3.91%**	**0.54%**

Sintel – 1080p



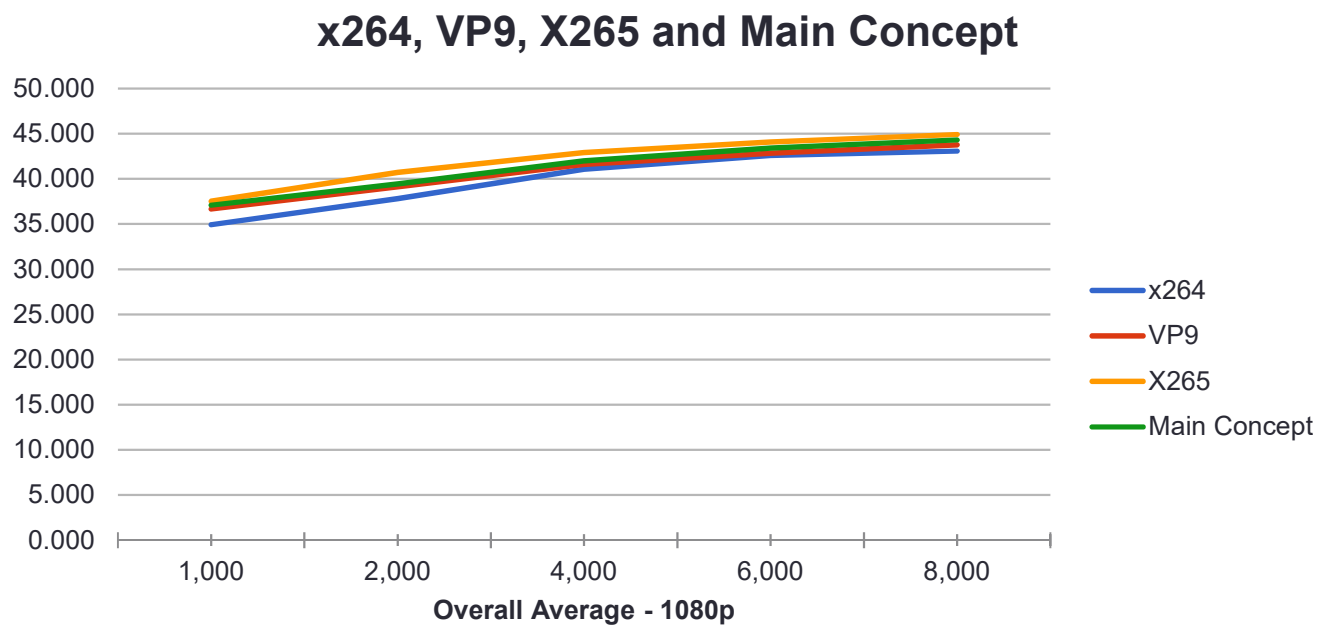
Sintel - 1080p	x264	VP9	X265	Main Concept	Max Delta	MC/X265
1,000	32.136	34.050	35.763	35.369	11.28%	-1.11%
2,000	35.590	36.953	38.742	37.630	8.86%	-2.95%
4,000	39.607	40.219	41.614	40.836	5.07%	-1.91%
6,000	41.613	41.980	43.240	42.723	3.91%	-1.21%
8,000	42.477	43.223	44.411	43.863	4.55%	-1.25%
Average	**38.284**	**39.285**	**40.754**	**40.084**	**6.45%**	**-1.67%**

Tears of Steel – 1080p



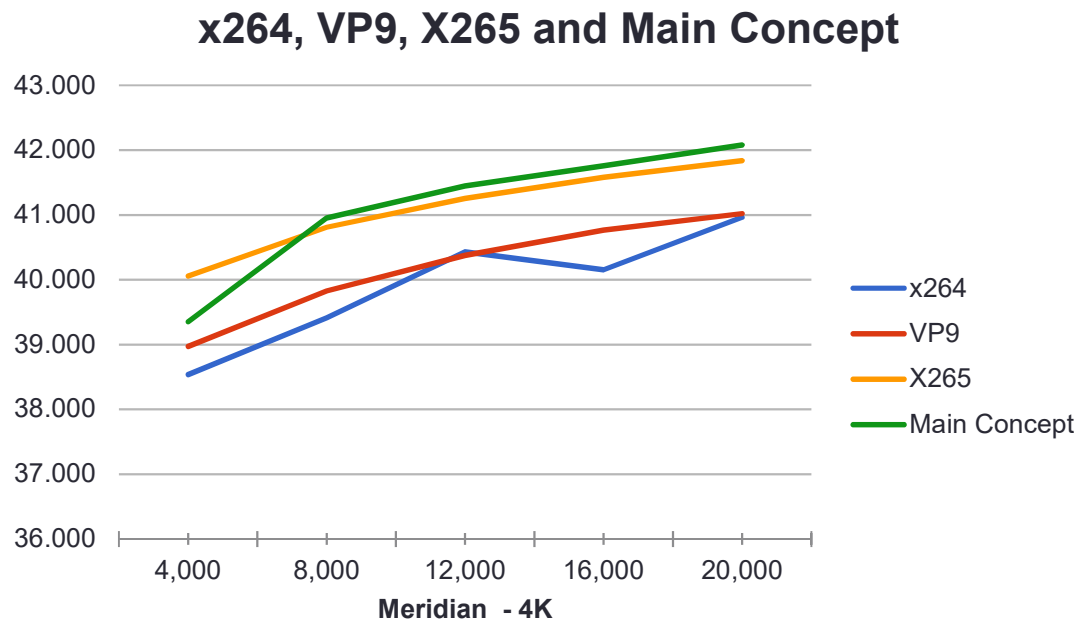
TOSN - 1080p	x264	VP9	X265	Main Concept	Max Delta	MC/X265
1,000	34.985	37.364	36.666	36.126	6.80%	-1.49%
2,000	38.238	40.261	41.680	39.180	9.00%	-6.38%
4,000	41.859	42.886	44.001	42.109	5.12%	-4.49%
6,000	43.454	44.105	45.158	43.701	3.92%	-3.33%
8,000	43.941	44.915	45.944	44.629	4.56%	-2.95%
Average	**40.495**	**41.906**	**42.690**	**41.149**	**5.42%**	**-3.74%**

Overall – 1080p



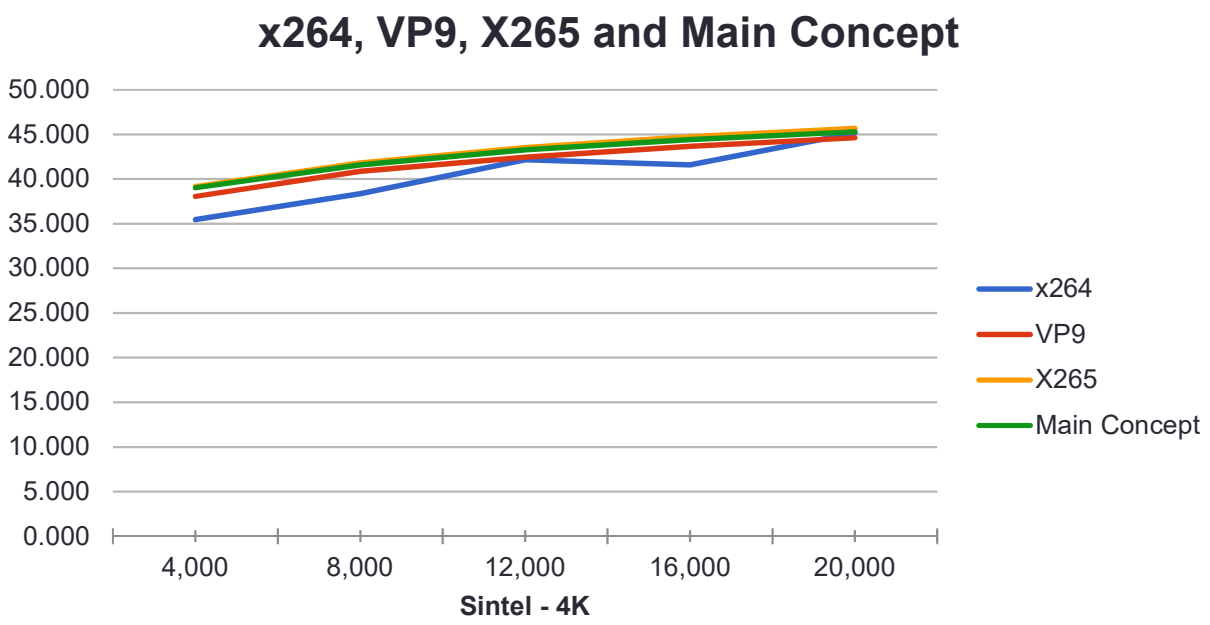
Overall Average - 1080p	x264	VP9	X265	Main Concept	Max Delta	MC/X265
1,000	34.934	36.664	37.525	37.093	7.42%	-1.16%
2,000	37.807	39.130	40.726	39.437	7.72%	-3.27%
4,000	41.063	41.591	42.903	41.981	4.48%	-2.20%
6,000	42.595	42.851	44.081	43.404	3.49%	-1.56%
8,000	43.074	43.772	44.912	44.312	4.27%	-1.35%
Average	**39.895**	**40.801**	**42.029**	**41.245**	**5.35%**	**-1.90%**

Meridian – 4K



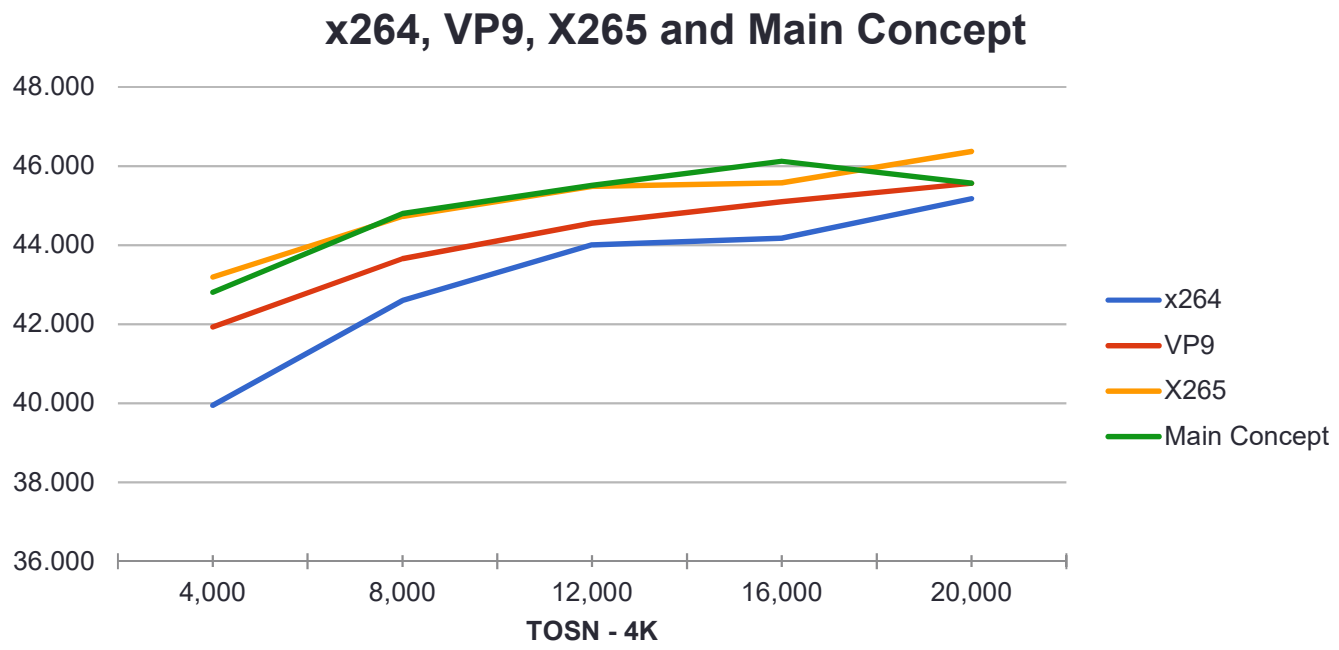
Meridian - 4K	x264	VP9	X265	Main Concept	Max Delta	MC/X265
4,000	38.537	38.971	40.057	39.353	3.95%	-1.79%
8,000	39.415	39.827	40.811	40.954	3.90%	0.35%
12,000	40.429	40.376	41.258	41.449	2.66%	0.46%
16,000	40.153	40.769	41.581	41.757	3.99%	0.42%
20,000	40.963	41.021	41.839	42.079	2.73%	0.57%
Average	**39.899**	**40.193**	**41.109**	**41.118**	**3.05%**	**0.02%**

Sintel – 4K



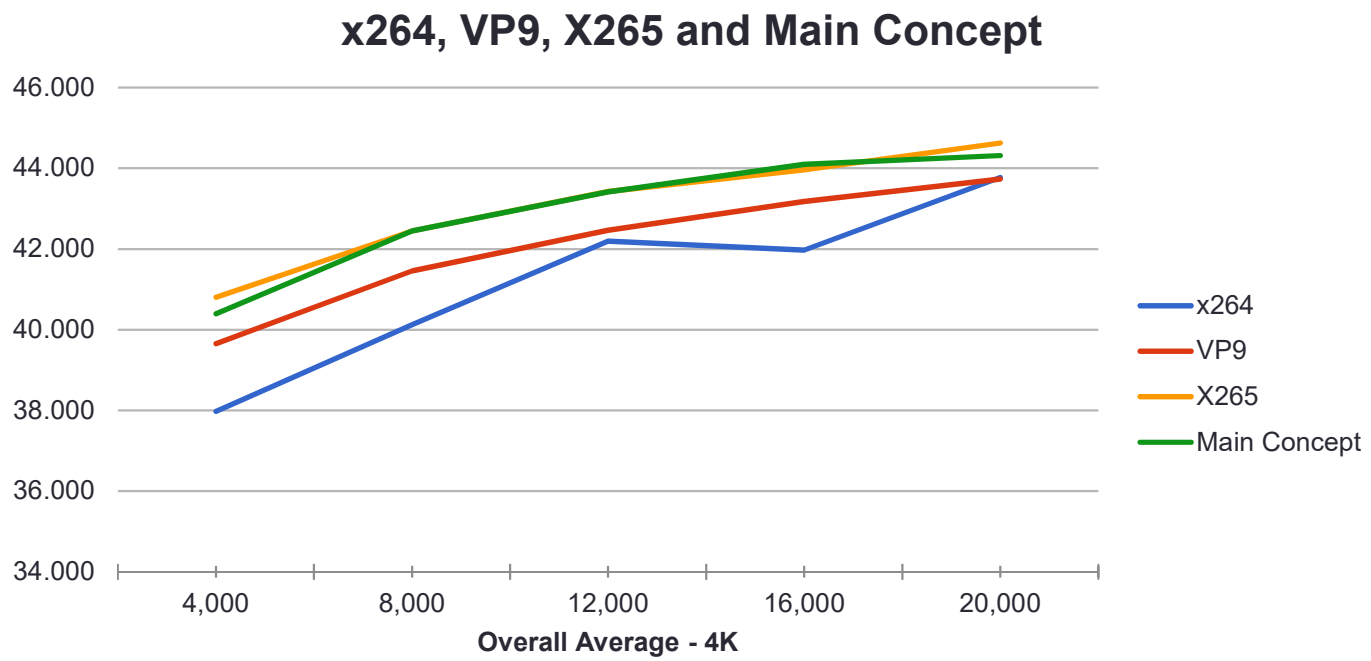
Sintel - 4K	x264	VP9	X265	Main Concept	Max Delta	MC/X265
4,000	35.451	38.066	39.169	39.026	10.49%	-0.37%
8,000	38.377	40.882	41.813	41.599	8.95%	-0.51%
12,000	42.149	42.459	43.522	43.290	3.26%	-0.54%
16,000	41.578	43.670	44.744	44.402	7.62%	-0.77%
20,000	45.175	44.614	45.668	45.296	2.36%	-0.82%
Average	**40.546**	**41.938**	**42.983**	**42.723**	**6.01%**	**-0.61%**

Tears of Steel – 4K



TOSN - 4K	x264	VP9	X265	Main Concept	Max Delta	MC/X265
4,000	39.946	41.928	43.190	42.805	8.12%	-0.90%
8,000	42.594	43.654	44.728	44.798	5.18%	0.16%
12,000	44.006	44.552	45.490	45.512	3.42%	0.05%
16,000	44.177	45.095	45.574	46.123	4.41%	1.19%
20,000	45.175	45.562	46.369	45.567	2.65%	-1.76%
Average	**43.179**	**44.158**	**45.070**	**44.961**	**4.38%**	**-0.24%**

Overall – 4K



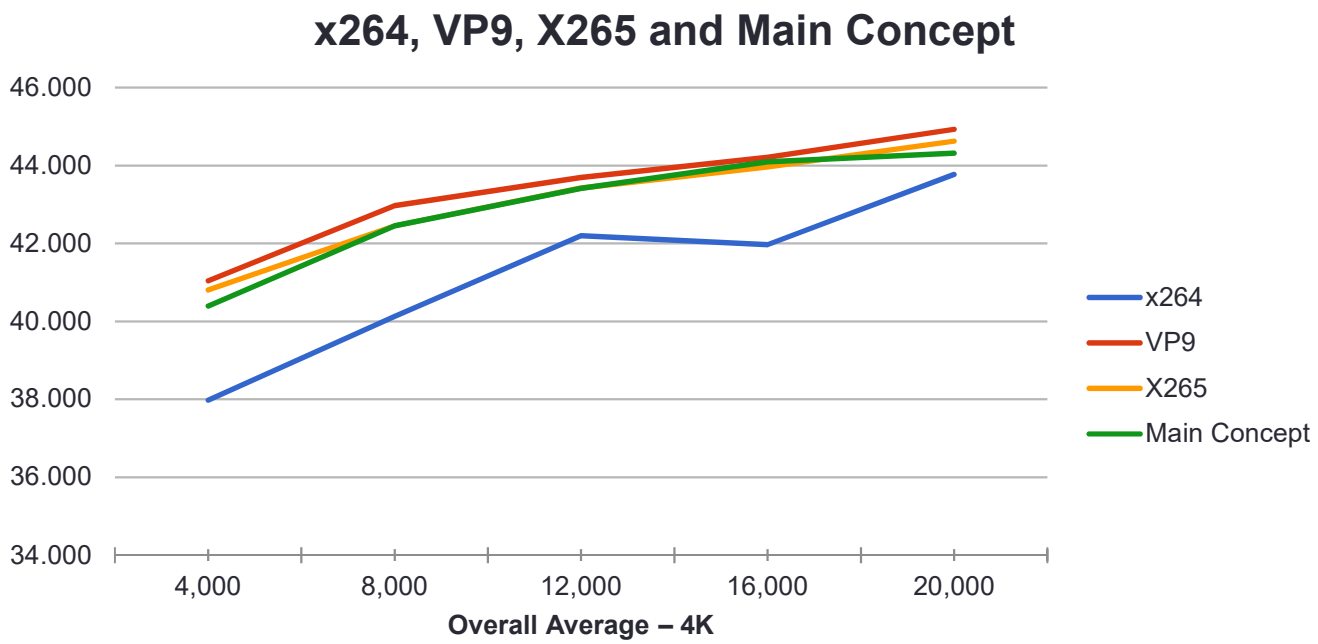
Overall Average - 4K	x264	VP9	X265	Main Concept	Max Delta	MC/X265
4,000	37.978	39.655	40.806	40.395	7.45%	-1.02%
8,000	40.128	41.454	42.450	42.450	5.79%	0.00%
12,000	42.195	42.462	43.423	43.417	2.91%	-0.01%
16,000	41.969	43.178	43.966	44.094	5.06%	0.29%
20,000	43.771	43.732	44.625	44.314	2.04%	-0.70%
Average	**41.208**	**42.096**	**43.054**	**42.934**	**4.48%**	**-0.28%**

Overall

Overall Average -	x264	VP9	X265	Main Concept	Max Delta	MC/X265
Level 1	35.569	36.128	36.511	36.374	2.65%	-0.38%
Level 2	36.285	36.727	37.059	37.059	2.13%	0.00%
Level 3	36.974	37.063	37.384	37.382	1.11%	-0.01%
Level 4	36.899	37.302	37.565	37.607	1.92%	0.11%
Level 5	37.500	37.487	37.784	37.681	0.79%	-0.28%
Average	**36.645**	**36.941**	**37.261**	**37.221**	**1.68%**	**-0.11%**

- H.264 looks comparatively strong
- X265 by a very small margin

4K – VP9 Encoded at 1



Overall Average - 4K	x264	VP9	X265	Main Concept	Max Delta	MC/X265
4,000	37.978	41.042	40.806	40.395	8.07%	-1.02%
8,000	40.128	42.970	42.450	42.450	7.08%	0.00%
12,000	42.195	43.689	43.423	43.417	3.54%	-0.01%
16,000	41.969	44.209	43.966	44.094	5.34%	0.29%
20,000	43.771	44.927	44.625	44.314	2.64%	-0.70%
Average	**41.208**	**43.367**	**43.054**	**42.934**	**5.24%**	**-0.28%**

Where Do We Go From Here

- Complete revamp of numbers:
  - I reencode, adjust timings as necessary
    - Re-encode x265 with PSNR tunings/Medium preset
    - Rencode x264 with PSNR tunings
  - Available at www.streaminglearningcenter.com by 3/15
  - Adjust this presentation and point out any key differences
- Going forward
  - Vanguard and perhaps one or two others by Streaming Media East (May)
  - Updated x265
  - Any updates to MC