

## Research Paper

# HDR-C

*High Dynamic Range Cinematography*



Completed with the aim of studying a semester abroad in U.S.  
and in mission of Austria Marshallplan Scholarship.  
Authored in San Diego State University

**Under the supervision of**

FH Prof. Mag. art. Markus Wintersberger

**Completed by**

*Max Wittmann*

San Diego, on June 25th

## Abstract

The goal of cinematography and photography is to capture an optimal image. To record the optimal image it has to be flexible in editing and postproduction. It is desirable to have control over the image in every detail. Through computer software it is possible to post process images from raw to get the best quality out of it.

In this research, I want to extract the developing process outside of the camera and process the image raw file in computer software.

Ultimately, the goal of this experiment is to produce a High Dynamic Range Sequence. The development of images with Photoshop HDR Pro was the main instrument for this research.

The images are recorded with Canon's 5D Mark1 Digital Single Lens Reflex Camera and transferred to process by a Mac computer. San Diego California's beaches provide for this experiment excellent scenario. Each of the three trials has a unique perspective of natural environment. Everytime, my question was: Why do images need HDR?

## Table of Contents

<b>ABSTRACT .....</b>	<b>2</b>
<b>TABLE OF CONTENTS.....</b>	<b>3</b>
<b>CHAPTER 1: INTRODUCTION .....</b>	<b>3</b>
<b>CHAPTER 2: CONTRAST PHOTOGRAPHY .....</b>	<b>4</b>
<b>CHAPTER 3: CONFLICT PROBLEM.....</b>	<b>10</b>
<b>CHAPTER 4 EXPERIMENTS .....</b>	<b>12</b>
<b>CHAPTER 5: CONCLUSION .....</b>	<b>27</b>
<b>REFERENCES .....</b>	<b>28</b>

## Chapter 1: Introduction

Is it important to know the contrast of a natural scene to get the optimal motion image in terms of high dynamic range?

This research focuses on the technical knowledge and discusses how an optimal image can be created. The experiment ultimately goal is to create a motion picture sequence with proper exposure to get a rich quality picture in high contrast scenery. A research methodic is chosen to investigate the light and shadow performance with a digital camera. The technique to record a high dynamic range image was used from still photographers many times before. For the test, the camera and the environment remains the same. The experiments are made with prime lens attached to a Digital Single Lens Reflex Camera. The images and the time-lapse scene were shot in California, U.S. and processed outside of the camera on Macintosh computer.

## Chapter 2: Contrast Photography

# Knowing the human eyes

Human's eye don't have to adjust like a camera for exposure. A minimum of light is necessary to see our environment and if there is too much light coming to the eyes we get blinded. In the lightest and the darkest part of an image we can still see details due to the contrast perception. As a result, adaption of the eye is possible to perceive a huge amount of dynamic range.

According to Wikipedia's definition, a human eye can handle a contrast of 1024:1 up to 16384:1 (that is between 11-14 Exposure Value). This is the dynamic range we can see and leads to the question of chapter 2:

Is the contrast range that a camera can archive less than a human eye? On the website of Adobe, there is a briefly description about contrast and brightness:

(...) The human eyes can adapt to very different brightness levels, most cameras and computer monitors can reproduce only a fixed dynamic range. Photographers, motion picture artists, and others working with digital images must be selective about what's important in a scene because they are working with a limited dynamic range.

High dynamic range (HDR) images open up a world of possibilities because they can represent the entire dynamic range of the visible world. Because all the luminance values in a real-world scene are represented proportionately and stored in an HDR image, adjusting the exposure of an HDR image is like adjusting the exposure when photographing a scene in the real world.

(Adobe, 2012  
[http://help.adobe.com/en\\_US/photoshop/cs/using/WSfd1234e1c4b69f30ea53e41001031ab64-78eea.html](http://help.adobe.com/en_US/photoshop/cs/using/WSfd1234e1c4b69f30ea53e41001031ab64-78eea.html))

## What is image quality?

At the most basic level, image quality comes down to a few simple things:

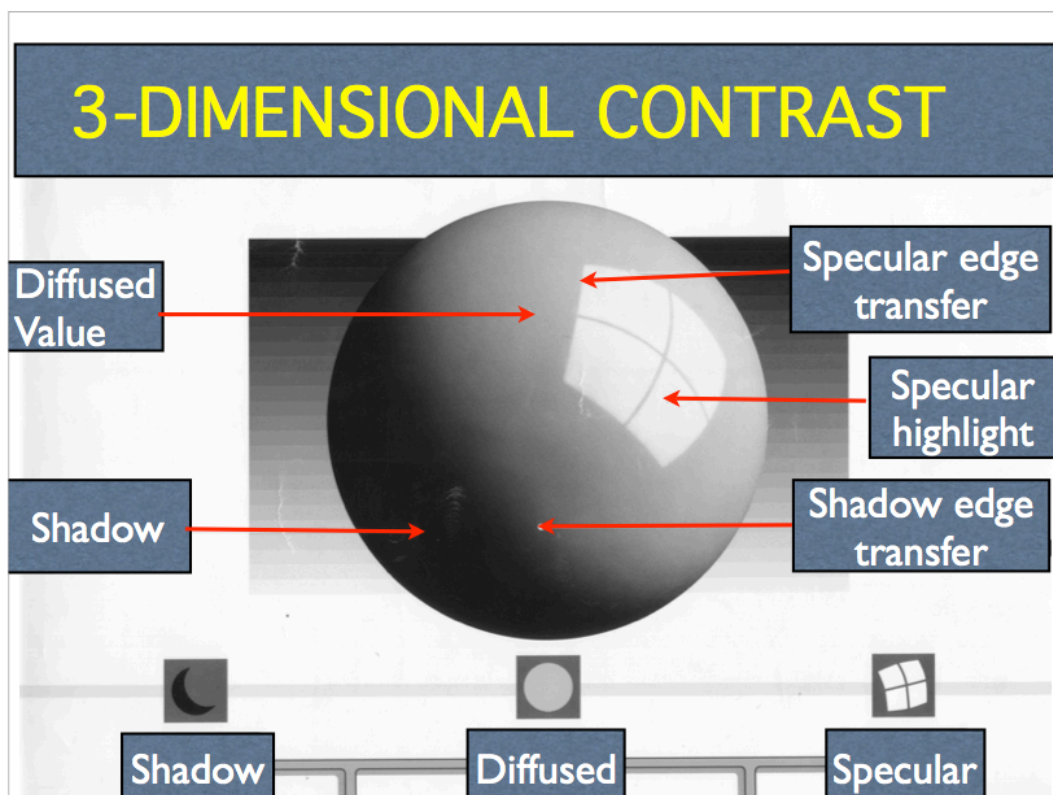
Optimal Contrast. We perceive images by seeing differences among tones. The more pronounced the differences (the higher the contrast), the easier it is to read an image, but only as long as you don't push contrast too far. Too much

contrast reduces too much of the image to black and white, destroying smooth transitions and tonal details—essentially, you lose image data. You get the best image quality when you've found the level of contrast that brings out the tonal details all the way from dark to light and tuned for the specific way you'll output an image, whether that's for a press or a monitor.

(Real World Adobe® Photoshop® CS5 for Photographers, 2011, Chapter 7)

## Existence of Dynamic Range

The graphic below gives an explanation about how objects reflect light in real world. This simple explanation is valid for every object in an image. But every object has a different reflection ratio.



**figure 1: 3-Dimensional contrast (SDSU, Rich Underwood PDF)**

Additionally to figure 1 there is direct light. When the light source is in the frame, it can be for example the sun. Interesting parts of the scenery and ultimately for the experiment are: Shadow and specular highlight.

Basically, a bright lightsource should not be in the frame. Digital cameras have difficulties in backlight situations and if there is a bright light source pointing on the camera lens there is a good chance to pollute the image with lens flare too. In photography dynamic range is measured in Exposure Value (EV) differences.

### **Media Types and Bits per channel**

Beside digital photography CCD and CMOS sensors, there exists also analog film.

#### **Film**

Celloide film features a very high dynamic range. That means theoretically infinite values of color tones (values) between shadow and highlight. Fotokem speaks about a contrast of 14 f-stops

#### **Digital**

Discrete values, Compression and quantization limit the quality and editing possibilities. DSLR camera Canon 5D Mark II features up to 11 stops dynamic range.

	Digital	Film
Dynamic range differences (EV stops)	11	14
quantization	discrete values 8 – 32bpc	practically infinite
Color room	RGB – Only colors in this space could exist.	consists of multiple film layers that respond to light differently

(compare [http://en.wikipedia.org/wiki/High\\_dynamic\\_range\\_imaging](http://en.wikipedia.org/wiki/High_dynamic_range_imaging))

Bits per channel (bpc) describe how many values are stored per color. For example a 8 Bit per channel image stores for each color 256 values. By multiply  $R*B*G$  the total color depth result to 24 Bit.



**image 1 This example was captured with Canon 5D mk1, Sunset Coronada San Diego**

Image 1 represents 10.5 stops dynamic range (Measured with HDR Expose 2). The analysis of the image demonstrates the spectrum of intensity. The highlight information is clipped. That happens when the highlight (the sun) has no more detail. This image is converted from a Canon Raw file with HDR Expose 2. Another issue in this image is the artifact creating blooming. If there is too much light, a crowing flower that affects also the area near by is created.

## Exposure for an optimal image

The technical side of photographing is very critical and for the test and experimental part it needs a lot of information about the objects in the frame. Although, the equipment is very expensive and should be selected based on the intended scene.

Proper exposure: It is the challenge to compromise where to set the exposure. The exposure value aperture and shutter speed define the amount of light traveling onto



the recording digital image sensor and exposure is one of the major parts of the whole experiment. Correct illumination leads to the success of these experiments.

#### Scenery (subject)

There is always a different light situation and each environment has different surface materials that change the way it reflects toward the lens. All objects in a scene create and reflect light and cast shadows that are related many times to each other. It is possible to measure the light coming onto the image sensor and finally the contrast values from the highlight and the shadow is never a mystery.

The lens is another important part for this experiment. The quality of the glass is as crucial as the camera.

<b>Specification</b>	Canon Eos 5D	<b>Specification</b>	Canon 50 mm lens
<b>Shutter speed</b>	Max. 3 frames per second	<b>Type</b>	Aspherical
<b>Exposure setting AEB</b>	-2EV 0EV +2EV	<b>Distortion</b>	No perspective distortion
<b>Timer</b>	Max. 99 photos then the timer needs a restart.	<b>Glass</b>	<ul style="list-style-type: none"> <li>• 7 elements / 6 groups</li> <li>• 2 high refraction glass elements</li> </ul>
<b>Tripod</b>	The camera has to stay on the same spot.	<b>Lens flare</b>	Somehow susceptible to flare

## Restrictions according to the experiment

### Environment and no artificial light in a natural scene

- Solid underground makes sure that there is no movement of the camera at all
- Predictable motion in the image sequence: No major movement of objects in the frame (movements outside the recording cycle interval are okay).
- The source light is in the frame (the sun)
- Shadow casted by objects



- High scene contrast: should be impossible to capture with a consumer camera. The blacks should be pitched black and the lights should be burned out (clipping both)

## **Scene information the photographer must know:**

- Light metering is essential to get a medium exposure value.
- Knowing the scene contrast (high to low) is important.
- Knowing the camera's functions.
- Have a bracketing or AEB function on the camera.
- Many digital cameras include an Auto Exposure Bracketing (AEB) option. When AEB is selected, the camera automatically takes three or more shots with a different exposure for each frame.  
(<http://www.hdr-photography.com/aeb.html>)
- With the information of scene contrast and the bracketing option it is possible to figure out how many frames should be recorded.
- Setup self timer: to take a sequence of pictures in a constant time interval.
- Recording interval: It is the challenge to choose the correct time period each time the camera records the image.

**Chapter 3: Conflict Problem****An example for a HDR photograph**

This is an example for High Dynamic Range Photography: The color details of this image are very rich. In terms of exposure, the image is optimal and the experiment's final goal is desirable to this image. Although, there is an additional saturation added to the image so that it looks similar to a painting and an artistic look.



**image 2: Visualization of a high dynamic range photograph of Balboa Park in San Diego, California. (image source: Wikipedia)**

## An example for Motion pictures

A 24 frames per second HDR Video as an example:



(image source stillframe from <http://www.youtube.com/watch?v=BlcLW2nrHaM>)

“Video is captured on two Canon 5D mark II DSLRs, each capturing the exact same subject via a beam splitter. The cameras are configured so that they record different exposure values, e.g., one camera is overexposed, the other underexposed.” (quote from Youtube [SovietMontage](#), 09-10-2010)

### Tonemapping

To display this work in a proper contrast it is necessary to tone map.

Wikipedia summarizes this technique like this:

Tone mapping is a technique used in image processing and computer graphics to map one set of colors to another in order to approximate the appearance of high dynamic range images in a medium that has a more limited dynamic range. Print-outs, CRT or LCD monitors, and projectors all have a limited dynamic range that is inadequate to reproduce the full range of light intensities present in natural scenes. Essentially, tone mapping addresses the problem of strong contrast reduction from the scene values (radiance) to the displayable range while preserving the image details and color appearance important to appreciate the original scene content.

(Wikipedia, 2012, [http://en.wikipedia.org/wiki/Tone\\_mapping](http://en.wikipedia.org/wiki/Tone_mapping))

## Chapter 4 Experiments

# The Test Environment

### The idea

The Scene setting is defined to a time-lapse situation. This solution focuses on objects in the frame that have a very slow time period to alternate. Clouds that move around and the sun are excellent objects due to their predictable, slow movement that can be captured by a 10-30 second interval.

### Overall goal

- Archive a detailed motion picture with a digital sensor with 16 bpc or even 32 bpc (Bits per channel) resolution
- Capture the dynamic range of a scene (no highlight clipping nor pitch black shadows)
- Clear lens quality

### - Scene & Subject

- Near San Diego, Ocean Beach
- Not overcasted, sunny day with clear view
- Highlight: Sun, or reflection for example water
- Shadow: Stone, - foreground, background
- Things with structural surface that reflect backlight (sun)
- Visible details in the sky (clouds)
- Vegetation for background separation (such as trees)
- Rich of colors and intensive colors

### - Camera equipment:

- Body: Canon EOS 5D mk1
- Lens: 28mm Olympus & 50mm Canon
- Selftimer
- Mattbox

### Processing:

- Macintosh: Mac OS X 10.6.8  
Macbook Pro (4GB RAM, 2.4 GHz Intel Core 2 Duo)

## An Approach

### HDR motion pictures mean that there is no compromise in exposure

For both image parts, the highlights and the shadows are essential information and a lot of details. For this reason, it is necessary to record the double amount frames.

However, it is possible to put two cameras shooting at the same time as demonstrated in the example above too. But this is expensive and it is hard to synchronize these two cameras.

This table compares normal cinematography vs. HDR Cinematography:

	Normal image	HDR image
Minimum images to record	Single image	Min. 2 images Merged together
Exposure	compromise	Full dynamic range: everytime optimal for highlight and shadow
Scenary	Can be anything	Fast movement makes it difficult to capture HDR

If the minimum of two images are recorded there would be one frame exposed for the highlight (sky) and another frame for the shadows (dark shadow objects). Another challenge are any kind of moving objects (objects change the place from one to the other bracketing exposure).

How can this problem be avoided so that we need multiple exposures for a high dynamic range image?

## Three Experiments

### Trial 1 Photography one HDR Image

#### Expected result:

1 image tone mapped (8Bit jpg)

Accomplished: San Diego 3/15/2012

#### Settings:

Experiment set to 3 RAW images. Each image is recorded in a different exposure value. Image 1 is overexposed by -2EV. Image 2 is exposed properly. Image 3 is underexposed by -2EV. The exposure values are varied by time according to the table below.

Parameter ISO SPEED: 100 - IRIS f/16

	EV f-stop	Exposure time
Image 1	+ 2	1/15
Image 2	0	1/60
Image 3	- 2	1/250

#### Processor (development process)

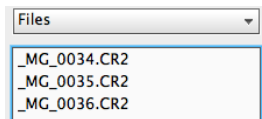
System: Macbook Pro 2011

Application: Photoshop CS5 / Merge to HDR Pro

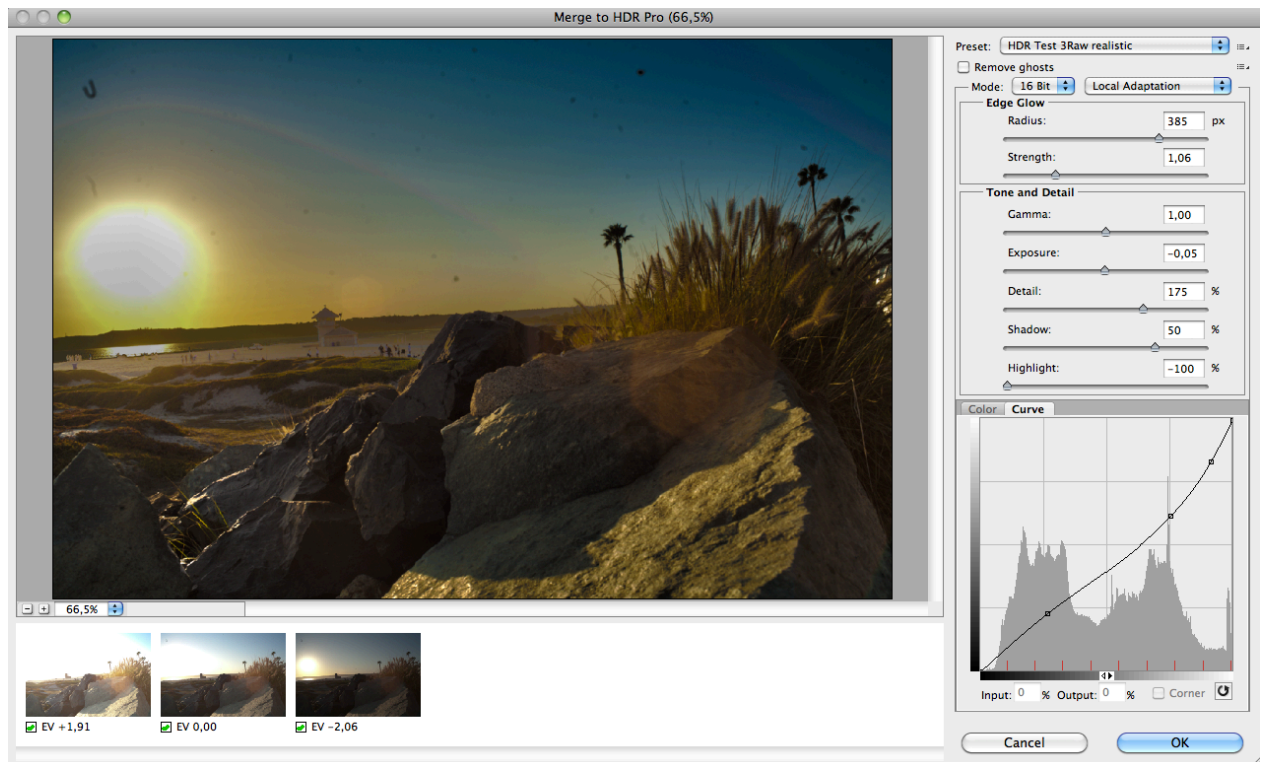
Workflow: Photoshop / File / Automate / Merge To HDR Pro...

Selecting the 3 different exposed images:





The 3 labor images (RAW files from the digital camera) move now to the raw processor on a Mac computer.



Based on the Photoshop Preset "Surrealistic HDR" some parametric changes get applied. The picture profile provides a more contrasted and crispier image.

Mode: change from 8Bit to 16Bit

# to offer enough values to allow fine transitions

Local Adaption

Edge Glow: Strength reduced to 1.06

# softens the image more, the local contrast gets less

Tone and Detail:

Set Shadow to 50%

# This opens the black shadows on the stones, brightens up the foreground

Highlight to -100%

# Restores a blue sky, adds more saturation and the sunball gets smaller to his actual size.

Curve:

The Curves feature displays a graph that plots the relationship between



input (unaltered) level and output (altered) level.

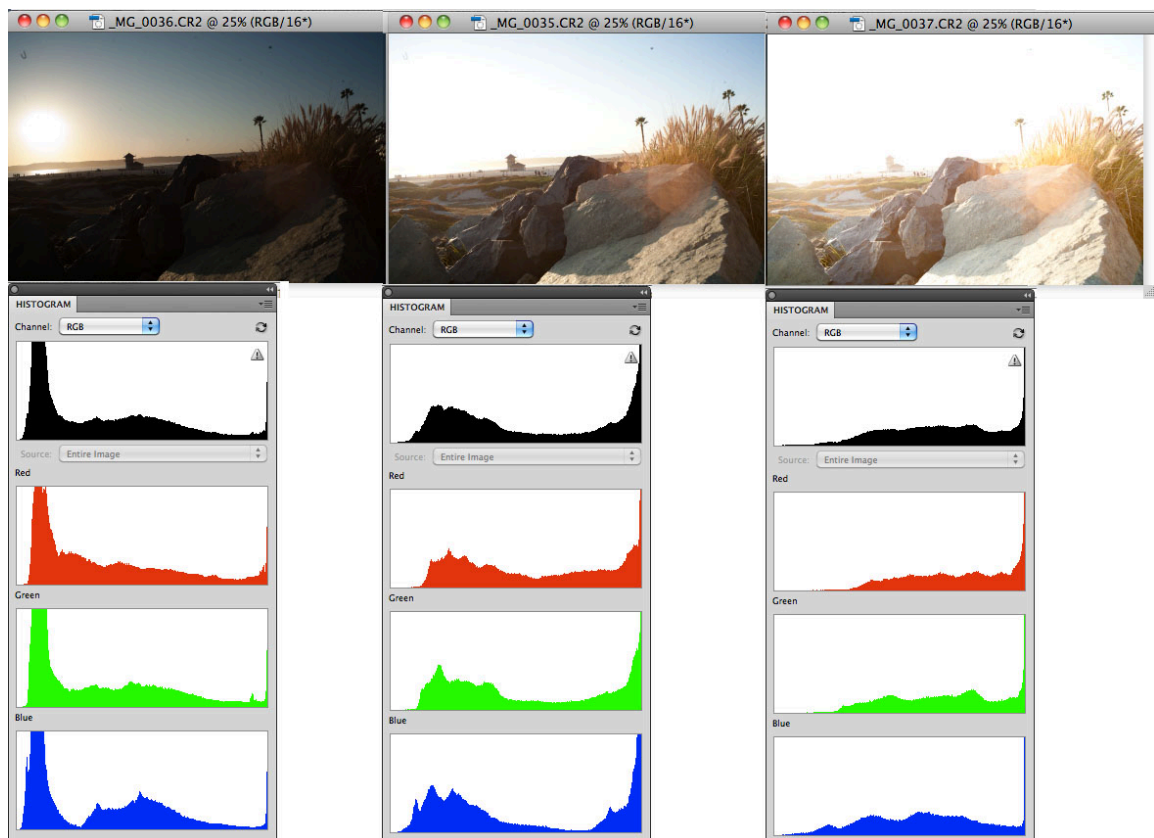
(Real World Adobe Photoshop CS5 for Photographers, 2011, Chapter 7 Hands on Curves)

Disable Corner

The soft curve reduces the highlight edge transfer from the clipping part of the sun to the sky.

## Analyze

Under critical view of the result, some issues were recognized:



**Image 3: three images produced from Canon Camera RAW; beyond the images: Photoshop Histogramm**

## Image Histogramm

To judge the entire tonal distribution at a glance. It is a graphical representation of the tonal distribution in a digital image (- Wikipedia)

The Luminance Histogramm (black)



**Image 4: The result of the first experiment: Photography one HDR Image**

**Completion:**

- Missing Clouds in the Sky

While recording (improvements for the next trial):

- Shoot with a higher quality lens
- Use Mattebox

More deeper shadows

Clipping report

- Generally The images are overexposed. This gets visible at the sunball were the bright lightsource is clipping. This results in a bigger lightsource than it actually is. The next exposure supposed to be lowered by -2EV (assumed)!

File format

- JPG allow 8Bit and high compession ratio. For further adjustments in image editing programs TIFF and PSD file format offers up to 32Bit per channel precision.

# Trial 2 Bracketing hdr/exr

## Expected result:

Preserve the maximum quality and dynamic of a Scene **in one image**.

1 image, more than 8Bit (16Bit/channel)

EXR file

## Settings:

Raw container: f-stop, picture profile, exposure

expose on Highlights!

4 exposes merged to HDR image; bracketing of a contrasty scene

## Processor

Photoshop / Merge to HDR

## **Capturing:**

HDR Test EOS 5D mark1

Lens: Olympus 28mm

Problem: light coming into lens (avoid lens flare)

Solution: stopping the direct light only for exposing the deep shadows.

Settings:	ISO 100	Aperture: variable	Time: variable
-----------	---------	--------------------	----------------

HDR Mode (a bunch of images with exposure variations): +1/-1 f stop each image

Bracketing: The bunch of images was captured within a minute.

## Process:

**Aim: Keep the image as flat as possible and process a 32bit imageformat.**

Workflow

Transferred CR2 Raw images to PC; Photoshop Merge to HDR w/32 Bit

Processing for Shadows

**4216 + 4217 open in HDR2**

Set Mode to 32 Bit >OK

Photoshop: Remove blocking light going into lens(in this scase the hands that suppose to be a mattebox)

Save as:

Photoshop (32Bit)

OpenEXR

Processing for Highlights

**4210 + 4213 open in HDR2**

Set Mode to 32 Bit >OK

Save as:

Photoshop (32Bit)

OpenEXR

#1 Merge this two HDRs together:

Both are still open in Photoshop

Add Open Files

**Cannot merge 32 Files!**

Changing from 32Bit down to 16Bit: Image>Mode

In the preferences window: choose preset **flat**

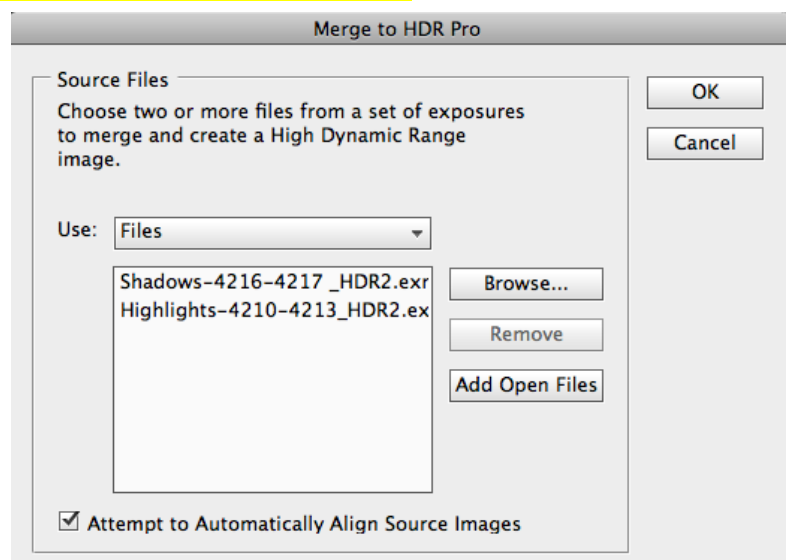
Save as psd

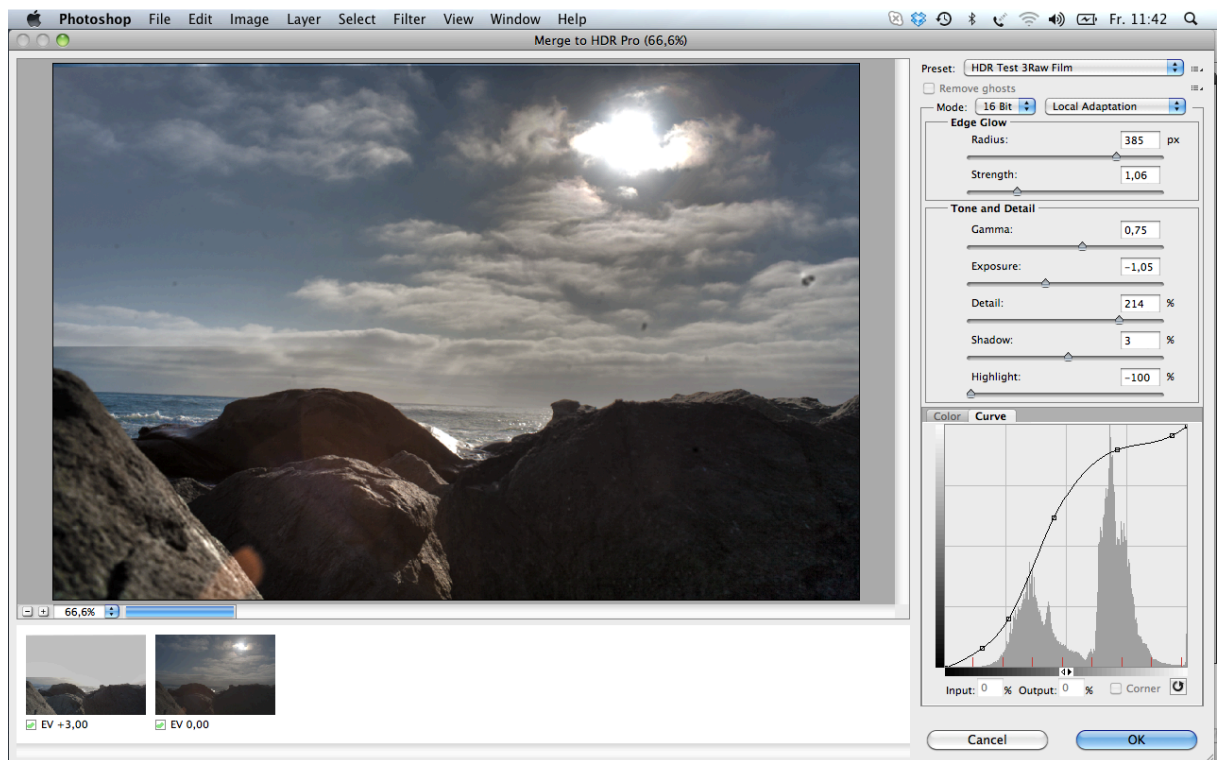
#2 Merge this two HDRs together:

**Cannot merge together if the images have a different size!**

Modify resolution

Sucessful start of processing





Modified accord to optimal picture (image); OK

Saved as: PSD and jpg (quality 6)

### MOD (Modifikation)

The shadows still have the lens flare. By modifying the highlight image, it is possible to remove the stones in the lower area of the image.

In highlights, there is a sharp line crossing in the far distance of the clouds. By modifying the softness of the threshold between this two merged images, another improvement is happening.

Test not possible to end: Photoshop don't process this two images together. Even if there is no report or any error message popping up

### Result

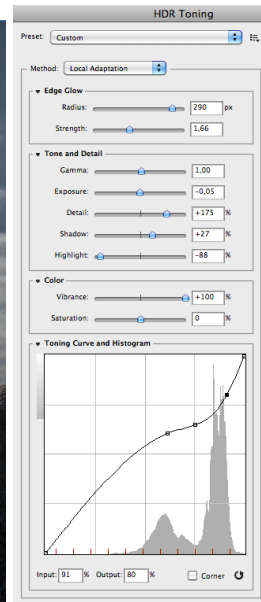
According to the test, there are several improvments:

Tripod was missing

Exposures correct

Test end. San Diego 01/30/2012 1:00 pm





The resulting 16Bit image can now readjusted with Photoshop image adjustments anytime and optimized for the scenery: In this case the shadows are more brighten up to see the effect of tone mapping.



## **Analyze**

The dark areas of the stones are well exposed. In the bright area the highlights are minimal overexposed (clipping of the sunball).

It was not possible to process the whole image in 32Bit. After retouching the shadow and the highlight images individually, it was not possible to merge them together anymore.

Contrast control is important not only for an entire image, but also for specific parts of an image. While that can mean adjusting contrast in specific areas of an image, it can also mean adjusting contrast within specific ranges of tones such as the shadows (for example, using Curves). Either way, manipulating contrast gives you the ability to treat specific areas that you want to clarify, emphasize, or de-emphasize.

(Real World Adobe® Photoshop® CS5 for Photographers, 2011, Chapter 7)





# TRIAL 3 Sequence

Expected result: a sequence of images in form of a time-lapse

- Container format .mov video file (10Bit ProRes)

## Settings:

Recording: RAW containerformat

Interval: Every 10-20 Seconds

4 seconds video

HDR Test EOS 5D mark1

Canon 50mm 1:1,4

## Processor

Photoshop / HDR (automation)

## **Capturing:**

Shot a sequence of photos with Canon 5Dmk1. Medium contrasty scene.

Settings:	ISO: 100	Aperture: f/8	Time: Variable
-----------	----------	---------------	----------------

HDR Mode (A sequence of 3 pictures with exposure variations): -2 0 +2

Bracketing: The times have been changed: **1/15 - 1/50 - 1/200**

**Note:** CF Card was replaced during the exposures (continue \_MG\_3863)

This unpredictable event caused camera shakenesses during recording.

Interval: Each 20 seconds (3 pictures in a row are captured)

This interval gets slower after 15 images (reduced from 11s to 20s interval)

## Process:

Workflow: Transferred 100 CR2 Raw images, select 67 images for further processing

**Modifying in HDR was not possible (app failure of HDR Pro2)**

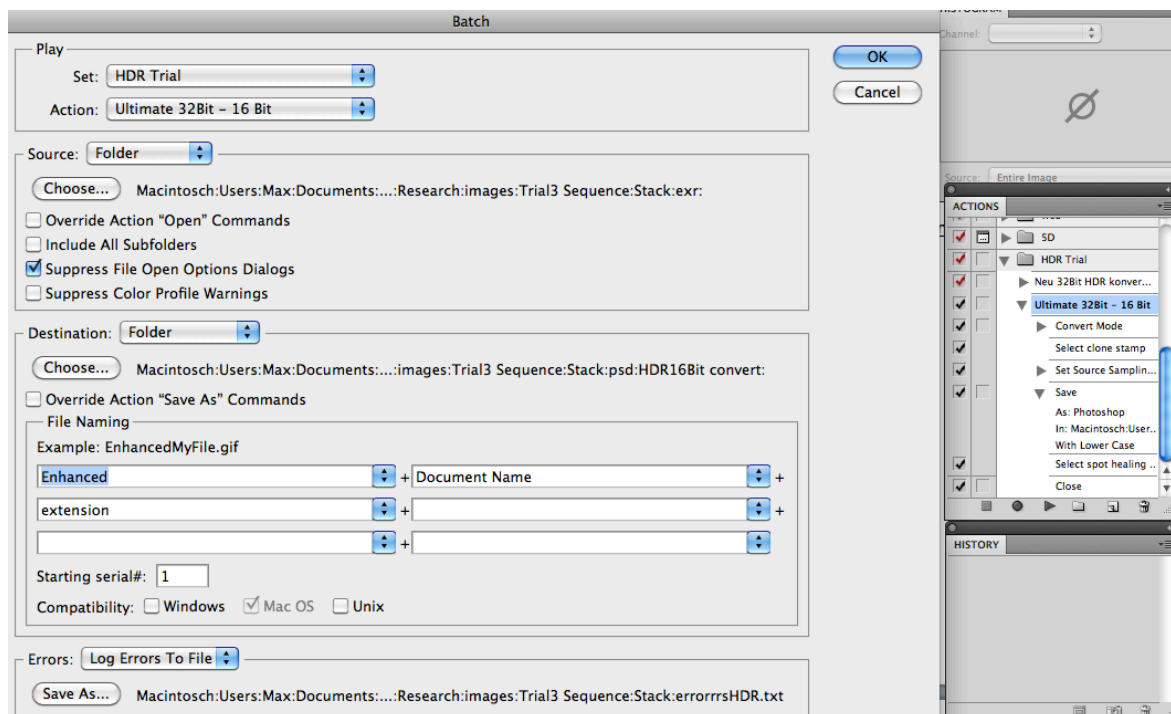
Manual HDR Merge in Photoshop:

Run Merge to HDR Pro Automation (like in previews test before)

Open every 3 raw files from sequence folder. In setup :merge up to 32Bit and apply remove ghosts effect. Save as exr file format.

**Editing 32Bit files in photoshop:** Setting tone curves in Aftereffects with 32 Bit footage is possible but the basic HDR toning features are very limited. Photoshop provides a more accurate tone curve and better image manipulation features.

With 67 converted images go to photoshop again. Set up an Automation for 32Bit to 16Bit conversion.



Apply detail filters and toncurve on two different images. Save automation as file (HDR Trial Action).

Start automation with image Untitled\_HDR201.exr – Every image get the same setting for curve and detail, then photoshop converts the image into a 16Bit per channel photoshop file and saves it.

After Effects CS5 – 67 psd images are imported as a sequence to After Effects. Create a new composition with 30 frames per second and 1080p resolution. The framing now has a little room for stabilize motion. Apply the stabilize to the sequence reduces the shakiness of the camera body during capturing the images. Exporting the Video in ProRes422 High Quality keeps the video in a proper quality for the finalization.

The last step removes some dusk from the image and extends the duration. Reimporting the video Sequence\_HDR-stable.mov and moved onto a new composition. Now tool clone stamp remove the dusk and a time remap

filter got applied. The duration is doubled to 134 frames. Frameinterpolation allows with frame mix to calculate frames between two real frames.

### Result

The final exporting format is a 10Bit ProRes mov and a 8Bit mov with h.264 codec.

According to the test, there are several improvements:

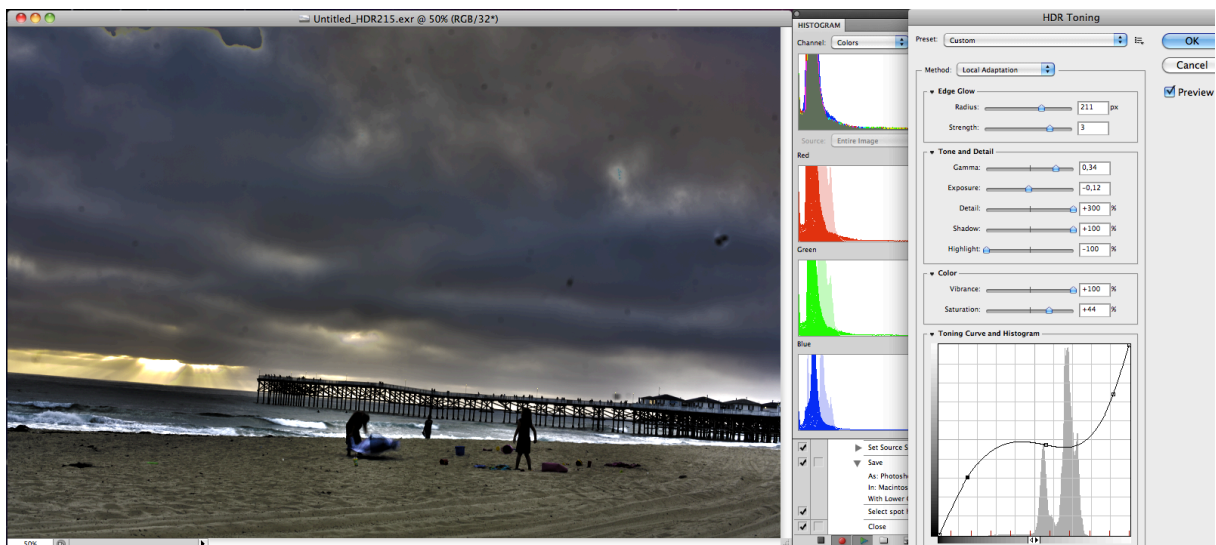
- Highlights missing (Sun not in picture)
- More deeper shadows
- Exposure correction +1 (test was underexposed 1 f stop)

### Reflection / Analyze

The full 32bit per channel image allows large editing capabilities. The very high dynamic range of 32bpc makes it possible to modify the toning curve vivid without creating artifacts.

Proper exposure gives the final result a crisp image with rich midtones, proper blacks and perfect exposed highlights.

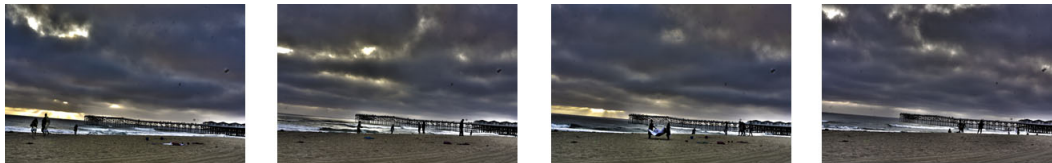
Furthermore the use of Raw and 32bpc allows filming a sunset without adjusting the exposure during recording. In editing is it very simple to control exposure with key frames. After Effects CS5 also support the 32bpc workflow with restrictions.



Test end. San Diego, Pacific Beach 06/01/2012 1:00 pm.

The HDR Sequence can be found at:

<http://youtu.be/DcHCIVuFH1Y>



## **Workflow**

32-bit per channel allows tremendous editing possibilities. Retouching the image in details are possible and this is why 16 bpc workflows are very common. On the other side more bits use a lot more storage and processing time. It is only a matter of time that 16bit and 32bit per channel workflows are standard in image manipulation. Finally HDR 32bpc is the ultimate colordepth for digital cinematographers.

Recording: Record the highest color depth that is possible with the camera. Record in RAW format if the raw workflow is possible on the editing machine. Some video cameras support ProRes 10 Bit recording (even that's for postproduction much better color depth than 8Bit).

Postprocessing:

There are many things to take care of:

It is obligatory to know the processing workflow. Shoot on a file format that is not tested on the editing machine is very negligently.

Even the fastest machine slows the HDR process down. The use of more bits means slower workflow speed. Higher hard disc capacities are needed.

## Chapter 5: Conclusion

In my opinion, each experiment was a different lesson and every trial was a new experience to photograph. It was never the same situation because the environment was every time different. There is no general preset or picture profile to photograph a landscape in a sunset. The light intensity is a big challenge. A good advice is: first, do the light metering and then do the math. It is very useful and be sure that you capture everything. Measure the darkest to the brightest part of the image. Record the pictures, don't forget to double-check your histogram on your camera. Think about the sunny 16 rule... it says: On a sunny day when the ISO is the same as the shutter Speed the F- Stop is set to  $f/16$  - add a half stop in California and then you are there!

## References

# Figures

*Figure 1: 3-D CONTRAST.pdf (Rich Underwood, 2012, p.1)*

# List of literature

**Filmmaking**, Focal press; 2011

ISBN: 978-0-240-81700-2

**Real World Adobe® Photoshop® CS5 for Photographers**, Peachpit Press,

Conrad Chavez, 2010

**ISBN-10:** 0-321-71983-2

**HDR Photography Secrets for digital photographers**, John Wiley & Sons, 2010, Rick Sammon

Ebook (Seattle library)

# Internet references

YouTube; [www.youtube.com](http://www.youtube.com)

Soviet montage

Excampe, HDR

[Http://www.youtube.com/watch?v=BlcLW2nrHaM](http://www.youtube.com/watch?v=BlcLW2nrHaM)

Wikipeda; [www.wikipedia.org](http://www.wikipedia.org)

Adobe: <http://help.adobe.com>