Practical Color Calibration for Mars Surface Images

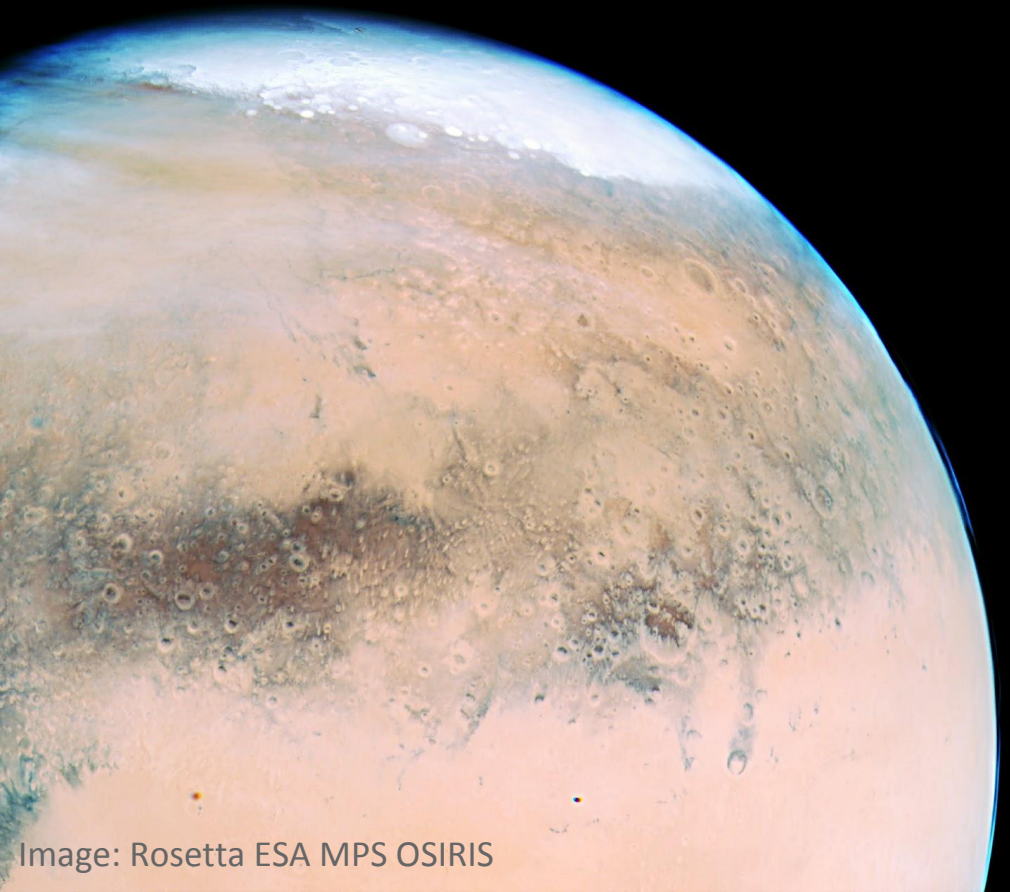


Image: Rosetta ESA MPS OSIRIS

Holger Isenberg
http://areo.info
holger.isenberg@gmail.com

Mars Society Convention
Irvine CA, 9/2017

Which colors
would a human perceive
on the surface of Mars?

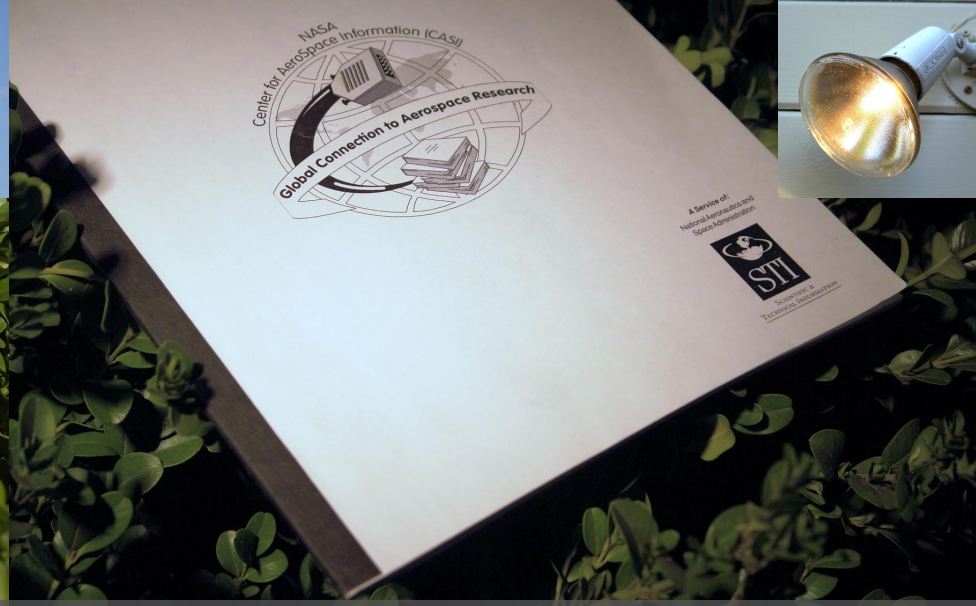
Which colors
does a human perceive
in different locations
on Earth?

Image: David McLeish
http://www.neatorama.com/2009/09/23/sydney-dust-storm

Sydney, during the 2009 dust storm

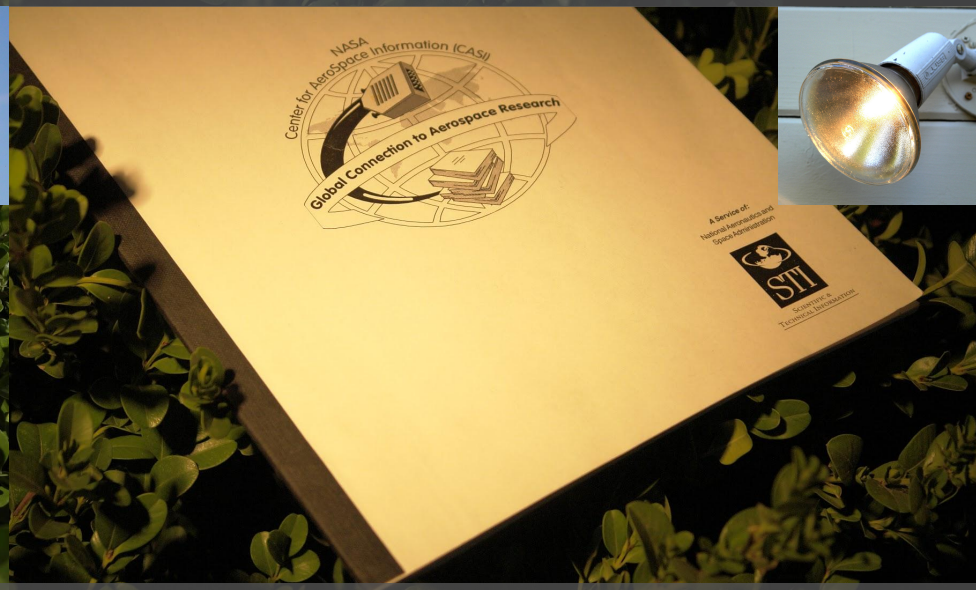
Automatic White Balance vs. Daylight Setting

Automatic White Balance



Automatic White Balance

Daylight Setting



Daylight Setting

Camera Profile:
Transforms Raw Camera Image into final product

Local Scene

take
Photo

Raw Camera Image

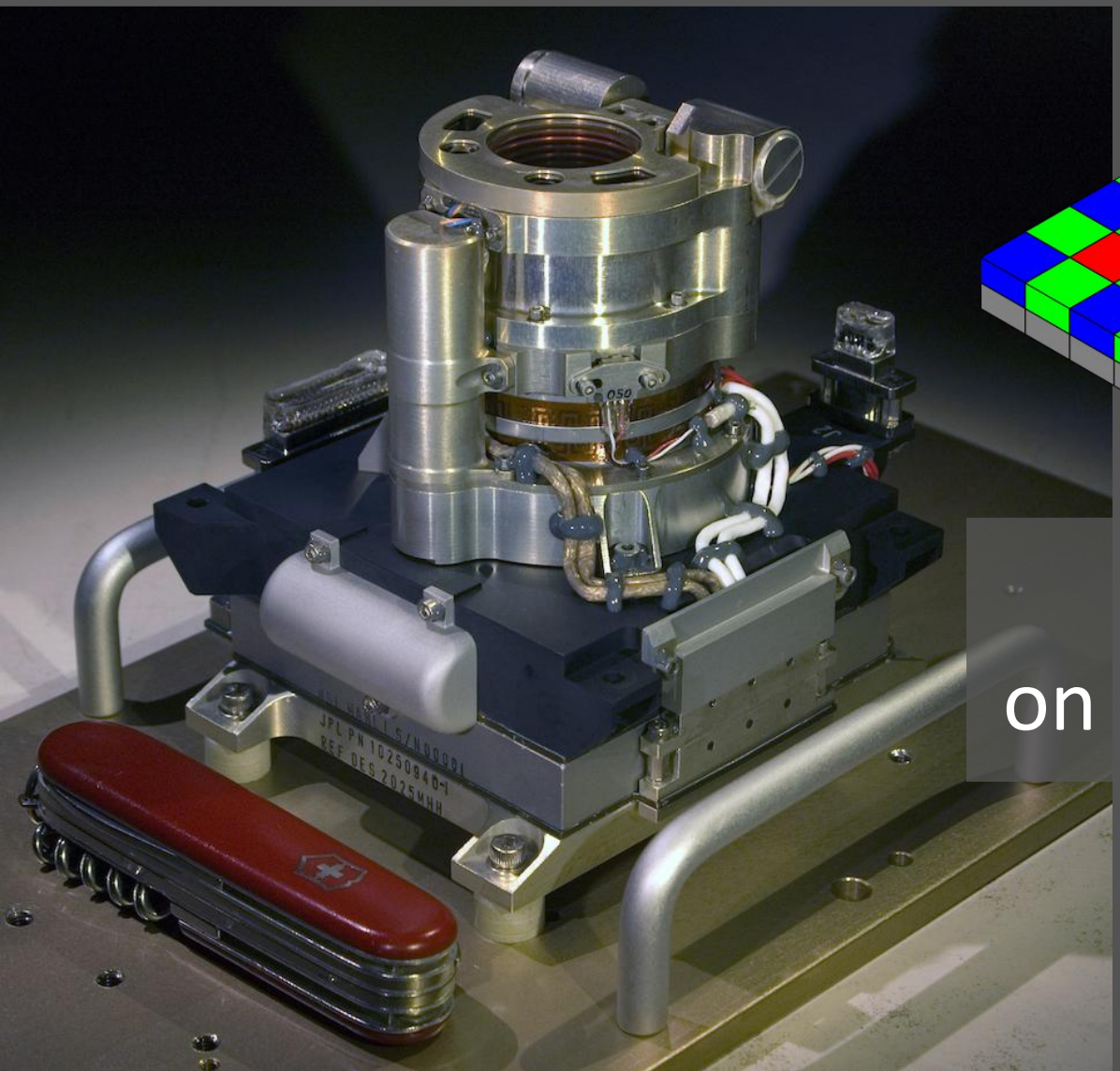
apply
Camera Profile
.ICC file

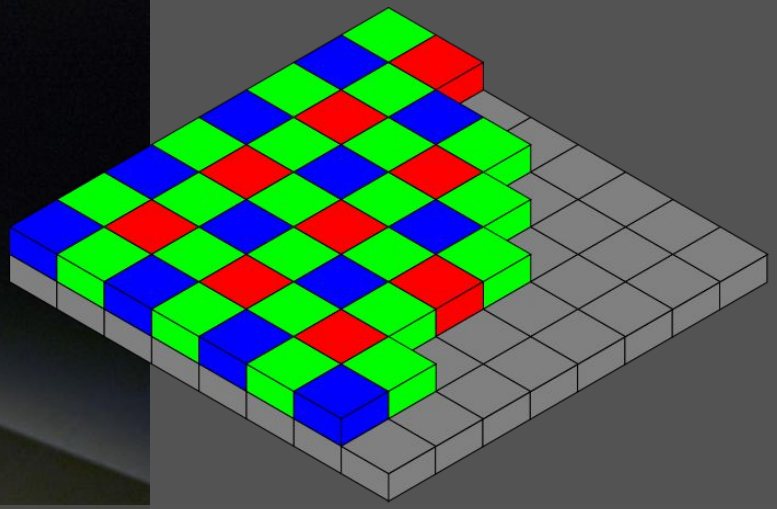
Final Calibrated Image

Creating a Camera Profile

http://www.ludd.ltu.se/~torger/photography/camera-profiling.html

MAHLI camera
Malin Space Science Systems

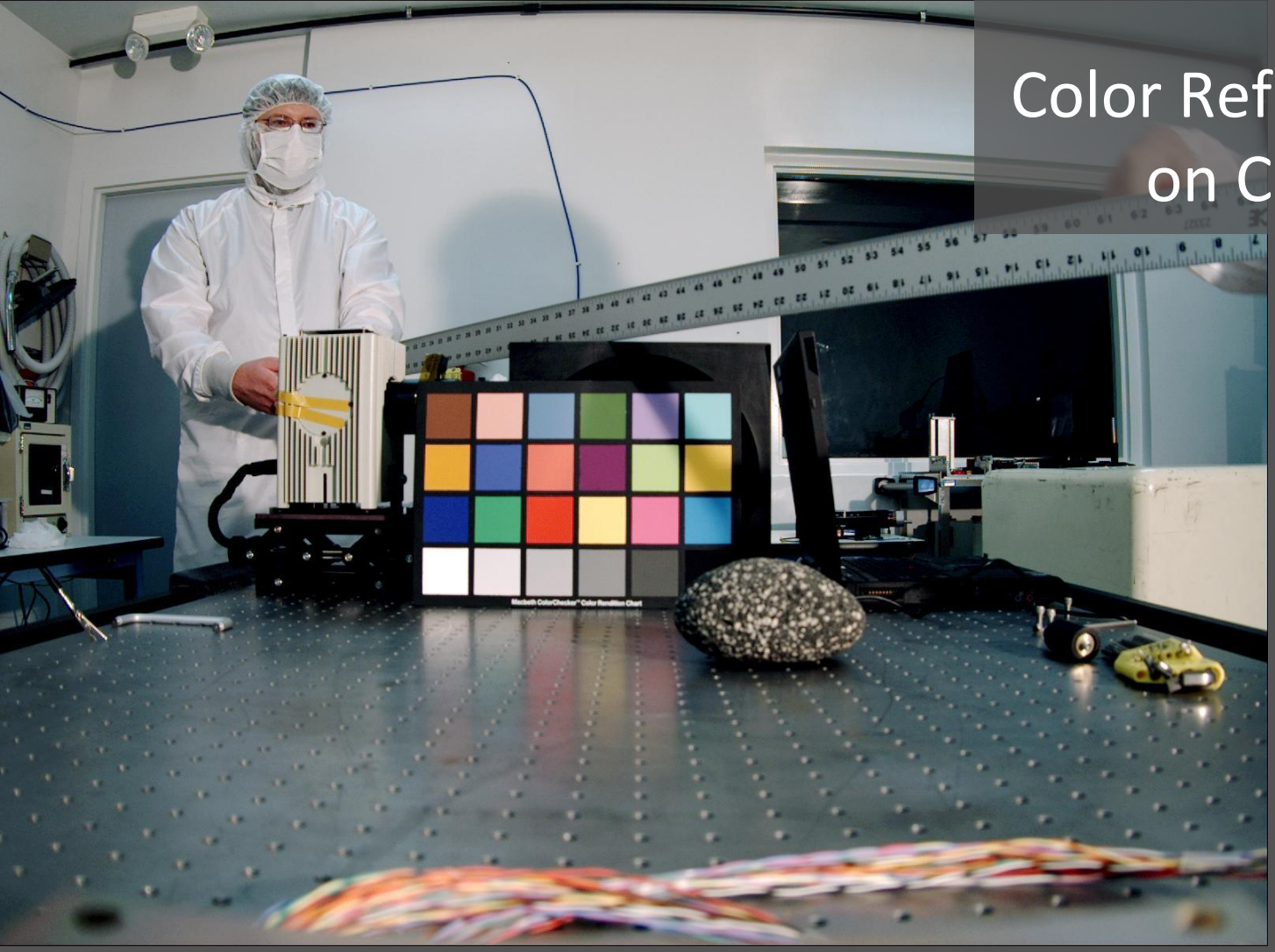




RGB Bayer Filter on CCD Image Sensor

Images:
http://www.msss.com/operations
https://en.wikipedia.org/wiki/Bayer_filter

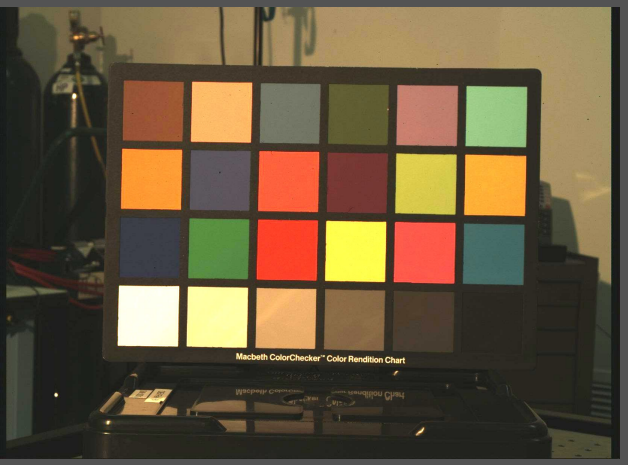
Color Reference Target on Curiosity Rover



Test images with Curiosity Rover Cameras
ColorChecker24 reference target
Malin Space Science Systems

https://photojournal.jpl.nasa.gov/catalog/PIA13281
https://photojournal.jpl.nasa.gov/catalog/PIA15286

Creating a Mars Camera Profile: Ingredients



- Reference Target: ColorChecker24
- Defined lightsource: NIST StdA
- Camera: MAHLI, Curiosity Rover
- Raw Image

- Software for creating a Camera profile: https://www.ludd.ltu.se/~torger/dcamprof.html:

- Mars Surface images in raw format: https://mars.nasa.gov/msl/multimedia/raw/

Creating a Mars Camera Profile: Process

- Linearize MAHL raw image:
  convert refimage.jpg -compress none -gamma 0.8 refimage.tif

- Extract color data from photo of ColorChecker24 reference target:
  scanin -v -p -dipn refimage.tif ColorChecker.cht cc24_ref.cie

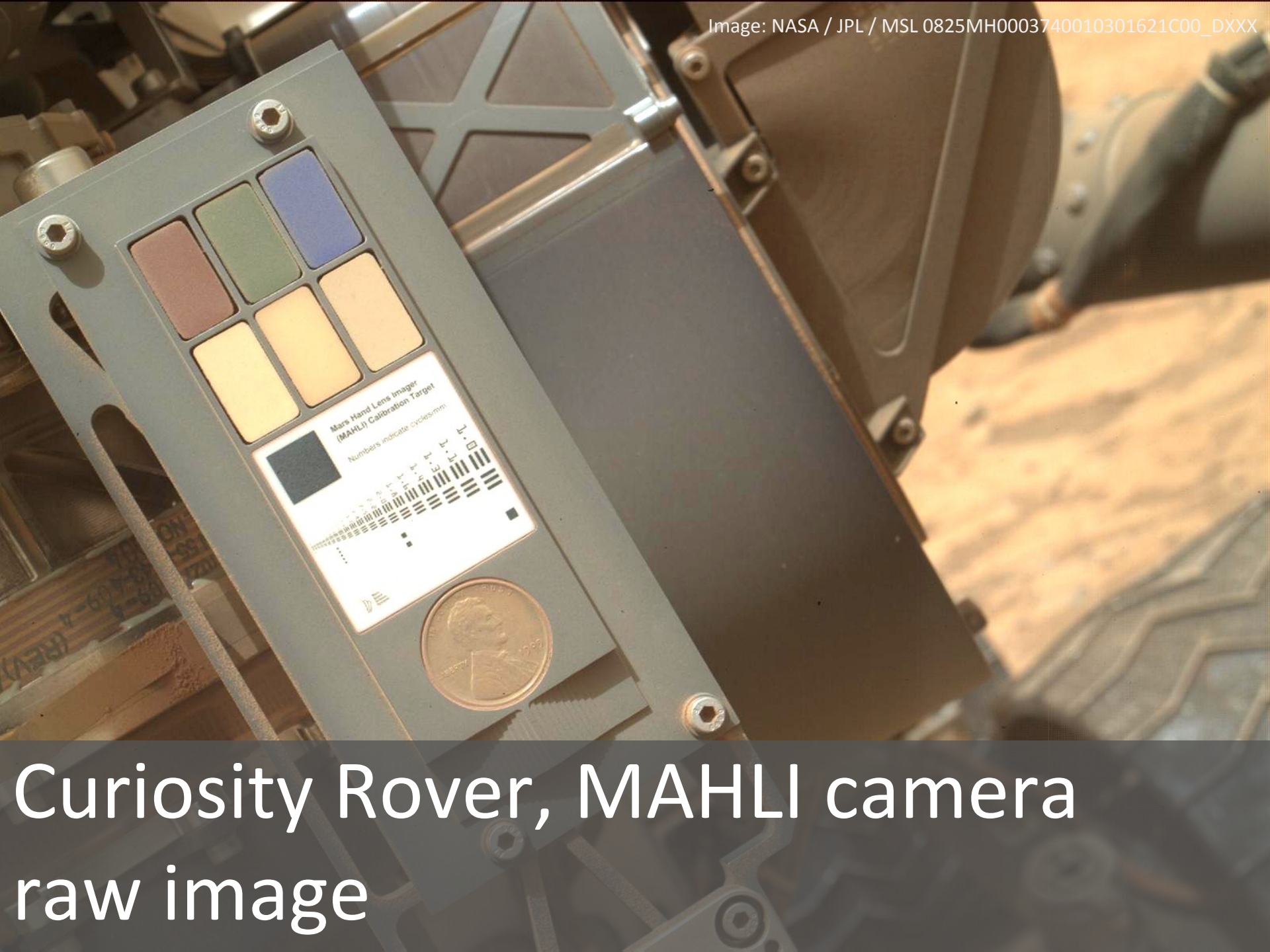
- Create the camera profile:
  dcamprof make-profile -i StdA -I D50 refimage.ti3 profile.icc

- Apply camera profile to Mars raw image:
  convert -gamma 0.5 -profile profile.icc rawimage.jpg calimage.jpg

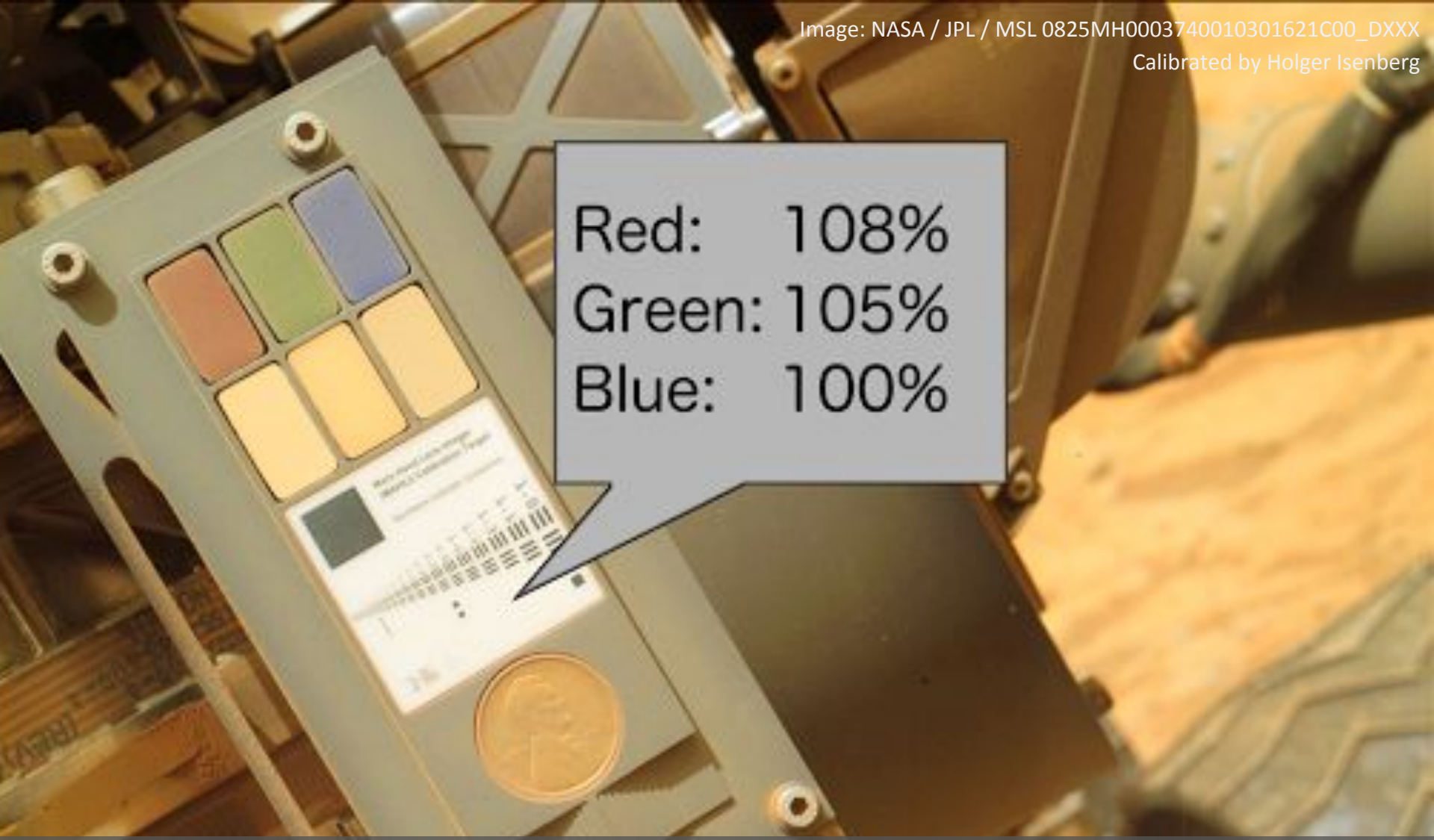
https://www.ludd.ltu.se/~torger/photography/camera-profiling.html
http://www.imagemagick.org/script/convert.php

Quality Report for Camera Profile
MAHLI, D50, from ColorChecker24 image

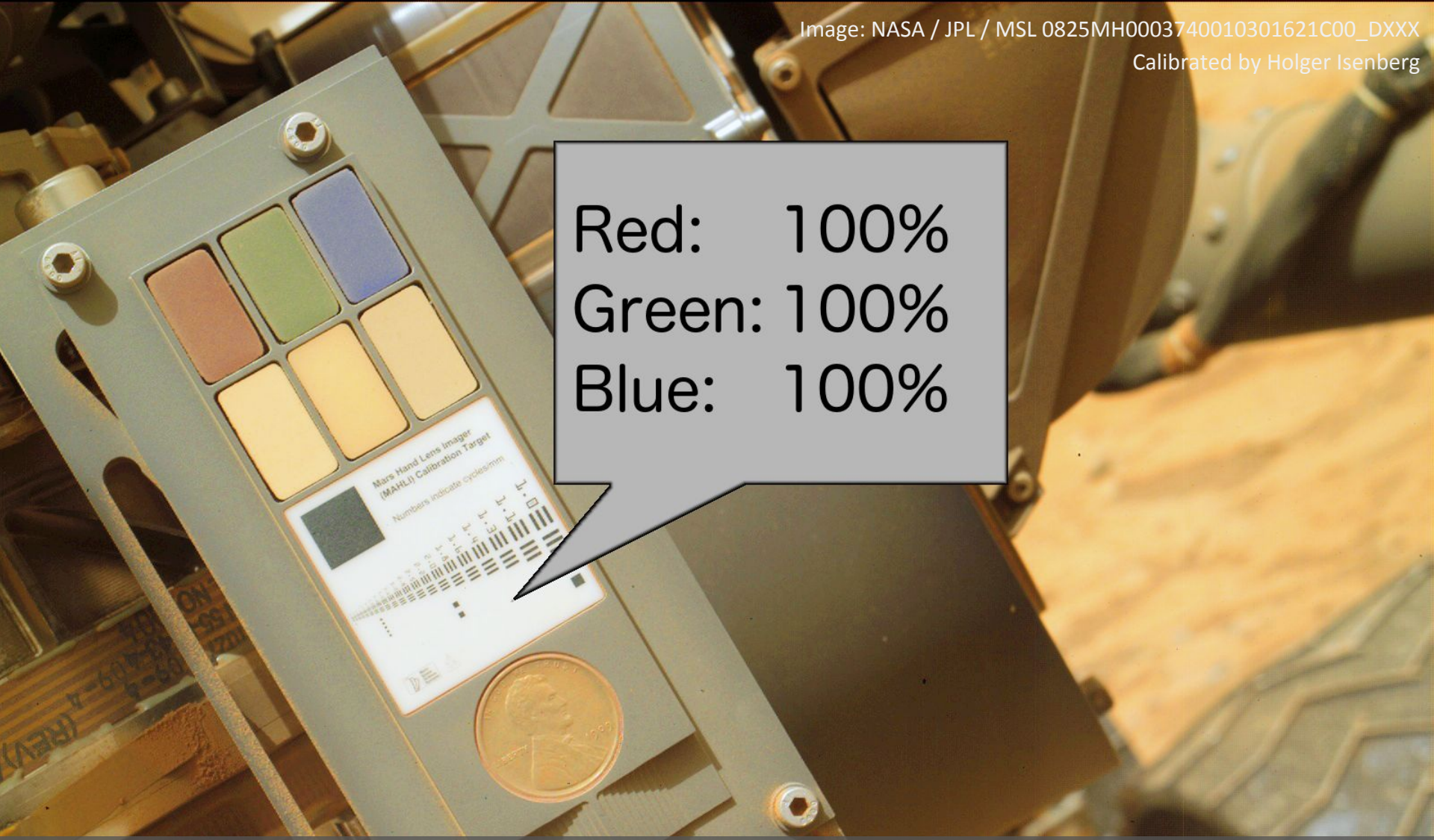
A01	DE 5.19	DE LCh	+5.13	-0.53	-0.61
A02	DE 2.30	DE LCh	+2.22	+0.07	-0.57
A03	DE 1.13	DE LCh	-0.31	+0.82	-0.47
A04	DE 2.31	DE LCh	+2.22	-0.20	+0.60
A05	DE 2.73	DE LCh	-2.70	+0.39	+0.19
A06	DE 2.77	DE LCh	-2.49	-0.70	+1.00
B01	DE 2.33	DE LCh	+0.69	-1.39	-1.74
B02	DE 0.98	DE LCh	+0.14	-0.42	-1.28
B03	DE 1.97	DE LCh	-0.56	-0.48	-1.83
B04	DE 2.42	DE LCh	+2.33	+0.09	-0.66
B05	DE 3.35	DE LCh	-1.66	-2.70	-1.09
B06	DE 5.43	DE LCh	-4.26	-3.09	-1.34
C01	DE 2.92	DE LCh	+2.71	-0.47	-1.42
C02	DE 3.48	DE LCh	+2.45	-2.38	+0.68
C03	DE 3.83	DE LCh	+3.15	-0.55	-2.12
C04	DE 3.40	DE LCh	-0.56	-3.35	+0.25
C05	DE 3.98	DE LCh	-3.53	+0.02	-1.82
C06	DE 4.08	DE LCh	-3.80	-0.23	+1.47
D01	DE 0.77	DE LCh	-0.54	+0.07	+0.55
D02	DE 0.00	DE LCh	+0.00	+0.00	+0.00
D03	DE 1.97	DE LCh	-1.89	+0.34	+0.42
D04	DE 2.14	DE LCh	-1.97	+0.81	+0.14
D05	DE 1.41	DE LCh	-1.14	+0.80	-0.21
D06	DE 4.38	DE LCh	+4.29	+0.62	-0.61



Curiosity Rover, MAHLI camera raw image



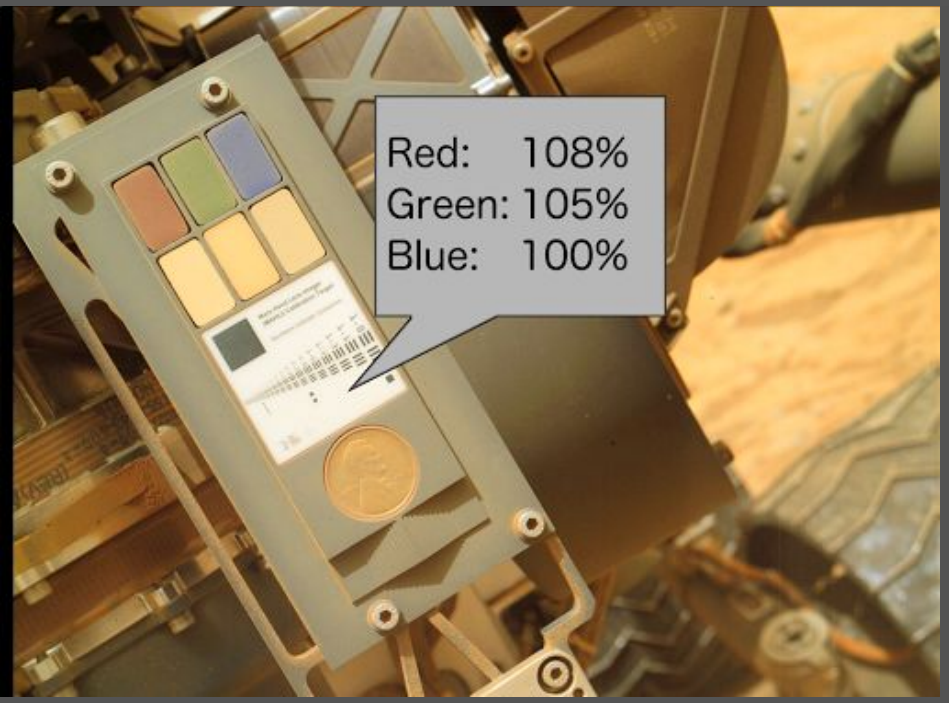
Curiosity Rover, MAHLI camera profile applied = daylight setting



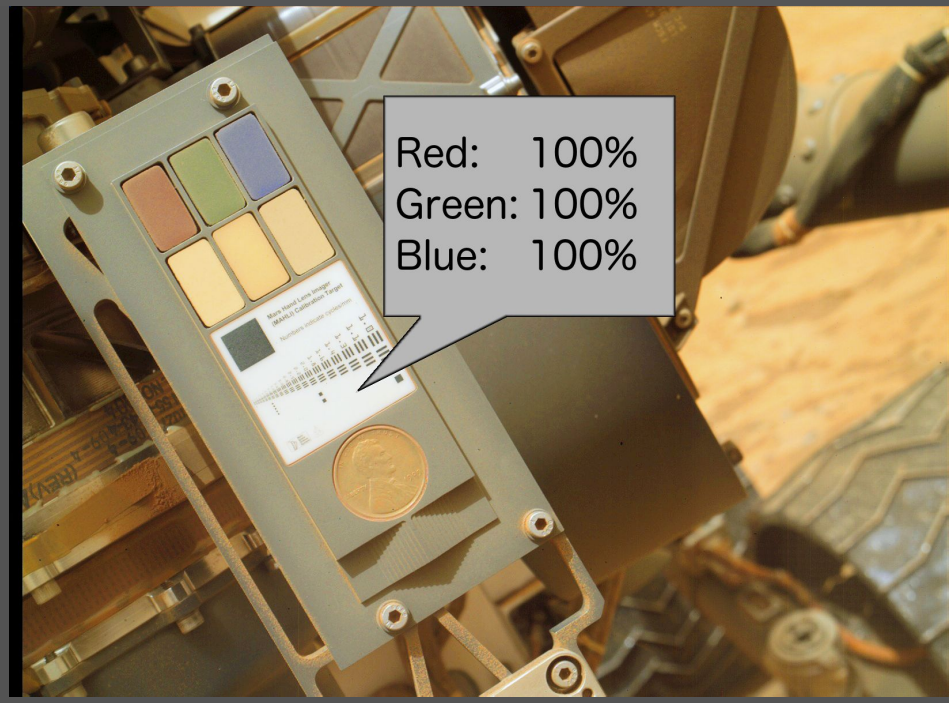
Curiosity Rover, MAHLI camera profile applied & white balanced

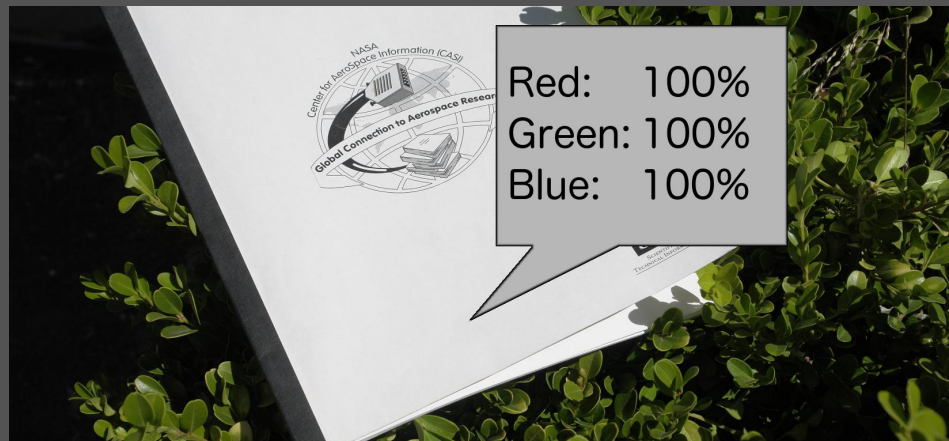
White Point during Clear Sky on Mars & Earth

daylight setting



white balanced





Earth-like colors on Mars
Sunlight like on Earth

Awesome result!

Need a 2nd opinion!

Viking Lander flight spare
National Air & Space Museum

Image: Holger Isenberg
National Air & Space Museum, Washington DC

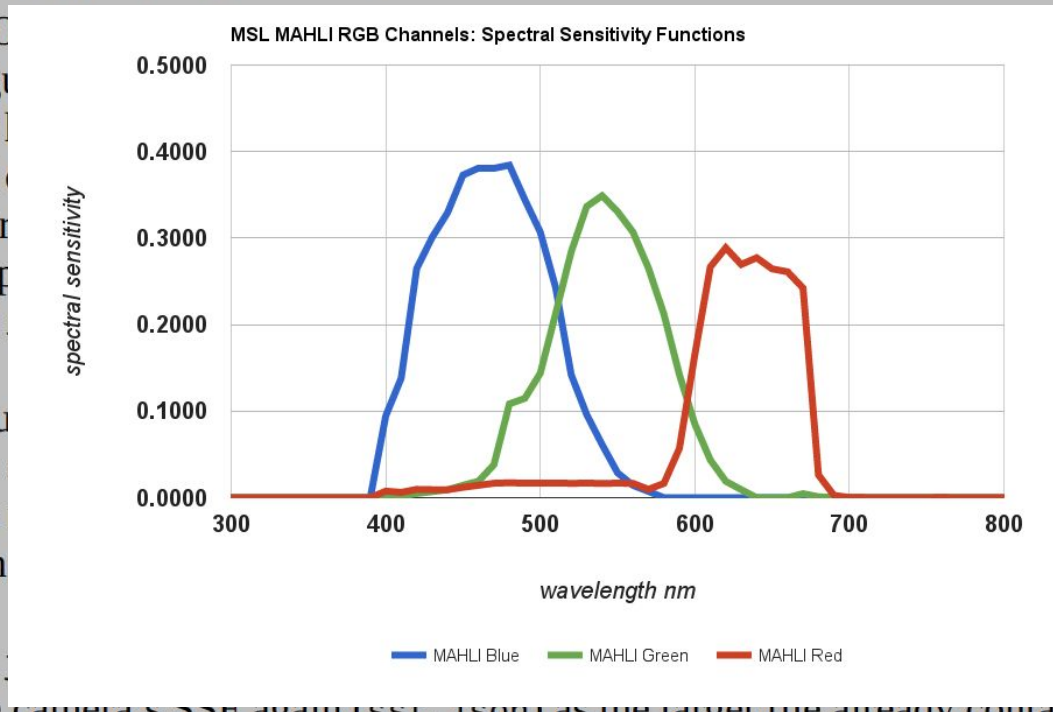
Unknown Color Reference Target
Image taken by Viking Lander Camera

www.ludd.ltu.se/~torger/dcamprof.html

Basic workflow for making a profile from camera SSFs

If you have the camera's spectral sensitivity functions you can skip the target shooting process.

1. Format your camera's SSF data into a JSC
   - Use the distributed examples as a gu
   - If you don't have the equipment or l section and see if you're lucky and
2. Generate a "virtual" target with your desir
   - You can use DCamProf's built-in sp other spectral source (see provided can use a subset).
   - Here's a basic example where we ju
     - `dcamprof make-target -c`
   - The resulting `target.ti3` contains values for the camera rendered usin
3. Make the profile
   - `dcamprof make-profile -c ssf.`
   - We don't really need to provide the camera's SSF again (ssf.json) as the target file already conta RGB and XYZ values, but it's a good habit since then the RGB (and XYZ) values will be regenera [illegible] reduces the risk of making mistakes.
   - If the SSFs are of high quality you will typically get a considerably better match with this than if y test target. This means that there is often less need of weighting and LUT relaxation when render profile.
4. Convert the native profile to a DNG profile or an ICC profile.
   - The scripts in the repo work by using templates [illegible] details.



Creating a Camera Profile
from the Camera's Spectral Sensitivity Functions
No photo of reference target required!

Camera Profile from Spectral Sensitivity Functions

- Create a virtual raw camera image of a ColorChecker24 reference target:

```
dcamprof make-target -i D50 -c ssf.json -p cc24 reftarget.ti3
```

- Calculate the camera profile from the virtual image:

```
dcamprof make-profile -c ssf.json -t acr reftarget.ti3 profile.icc
```

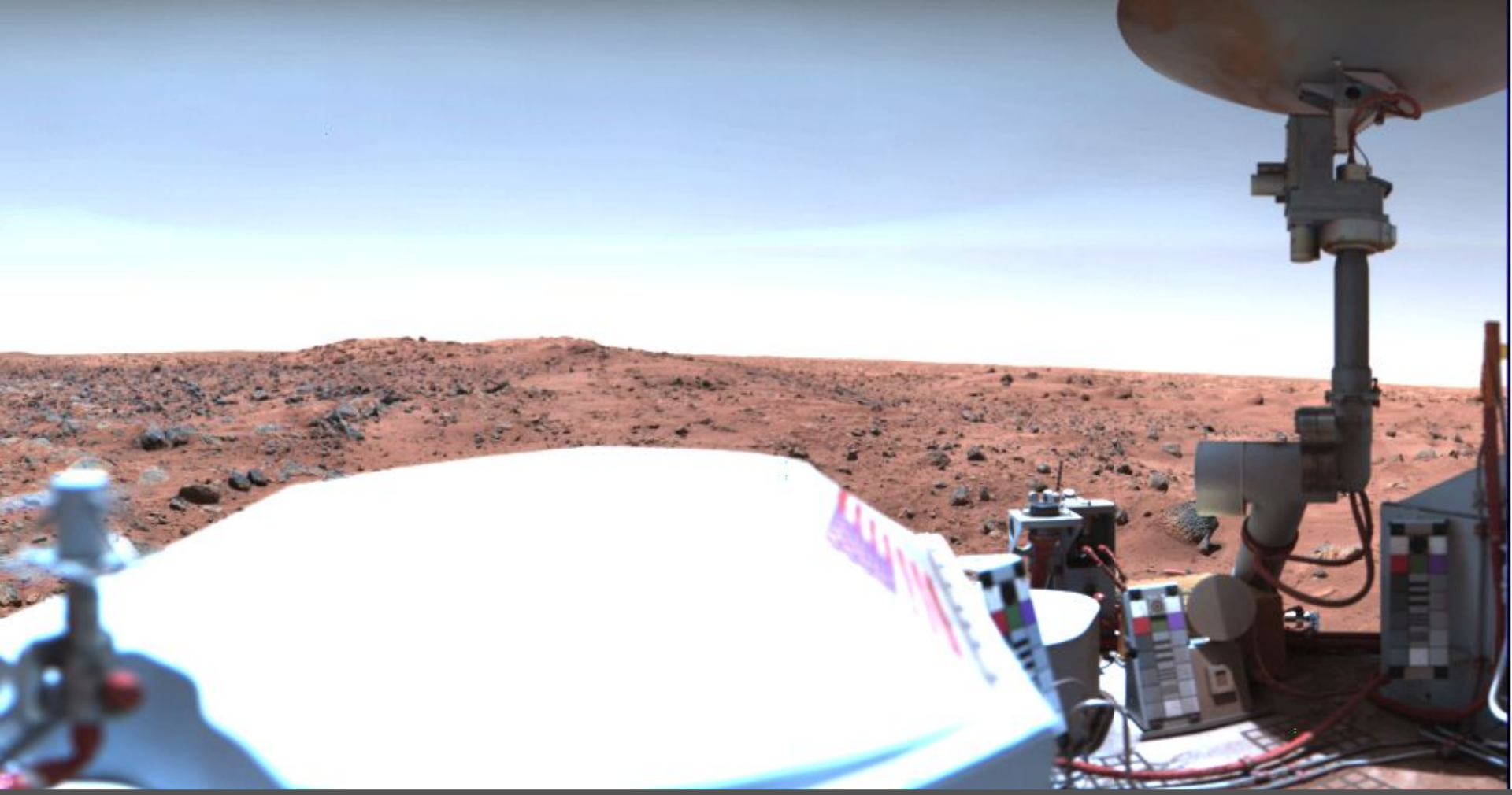
- Apply camera profile to Mars raw image:

```
convert -gamma 0.5 -profile profile.icc rawimage.jpg calimage.jpg
```

https://www.ludd.ltu.se/~torger/dcamprof.html#workflow_ssf
http://www.imagemagick.org/script/convert.php

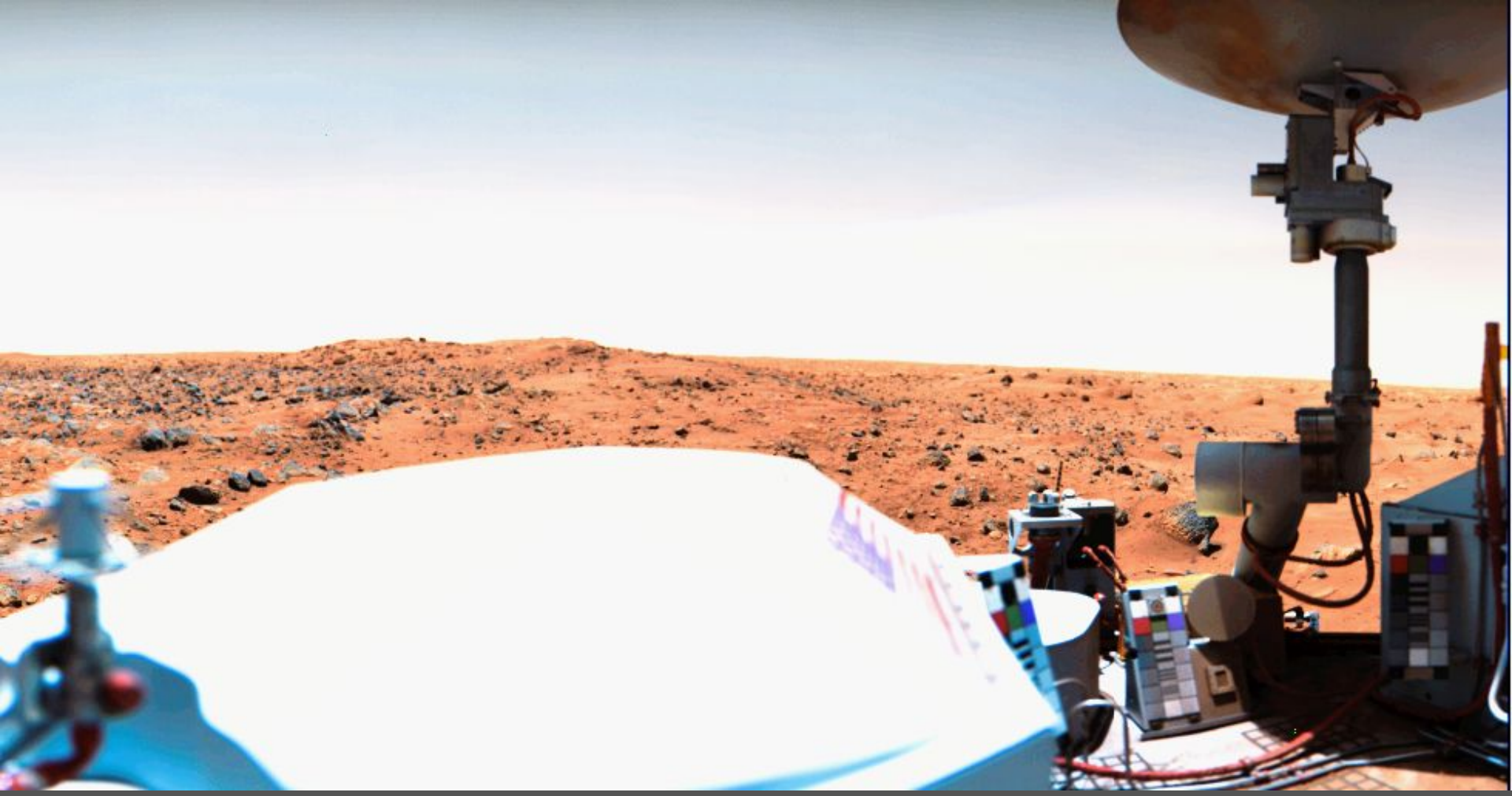
Quality Report for Camera Profile
Viking Lander 1, Camera 2, D50, from SSF

A01	DE	0.72	DE	LCh	+0.41	-0.10	-0.58	C01	DE	1.21	DE	LCh	-0.40	-0.48	-1.47
A02	DE	1.12	DE	LCh	+0.94	+0.06	-0.60	C02	DE	2.83	DE	LCh	+1.45	-2.41	+0.31
A03	DE	1.25	DE	LCh	+0.13	-0.90	+0.60	C03	DE	6.80	DE	LCh	+6.48	+0.17	-2.06
A04	DE	1.35	DE	LCh	+1.16	+0.31	-0.61	C04	DE	3.82	DE	LCh	+0.90	-3.71	-0.04
A05	DE	1.37	DE	LCh	+1.16	-0.24	+0.58	C05	DE	4.35	DE	LCh	+4.07	-0.03	+1.55
A06	DE	1.41	DE	LCh	+0.84	-0.75	+0.86	C06	DE	1.58	DE	LCh	+0.74	-0.28	+1.36
B01	DE	2.16	DE	LCh	+0.36	-1.33	-1.66	D01	DE	1.03	DE	LCh	+0.11	+0.42	-0.94
B02	DE	1.98	DE	LCh	+0.81	-0.57	+1.31	D02	DE	0.00	DE	LCh	+0.00	+0.00	+0.00
B03	DE	1.77	DE	LCh	+1.11	-0.82	-1.10	D03	DE	0.90	DE	LCh	-0.08	+0.69	-0.57
B04	DE	4.64	DE	LCh	+4.59	-0.14	+0.64	D04	DE	1.06	DE	LCh	-0.12	+0.97	-0.40
B05	DE	3.32	DE	LCh	+0.98	-2.79	-1.52	D05	DE	0.70	DE	LCh	-0.06	+0.49	-0.50
B06	DE	3.45	DE	LCh	+0.66	-3.16	+1.24	D06	DE	0.43	DE	LCh	+0.04	+0.31	+0.29



Viking Lander 1, 1976
raw digital image

Viking Lander 1, 1976
Camera Profile applied
daylight setting

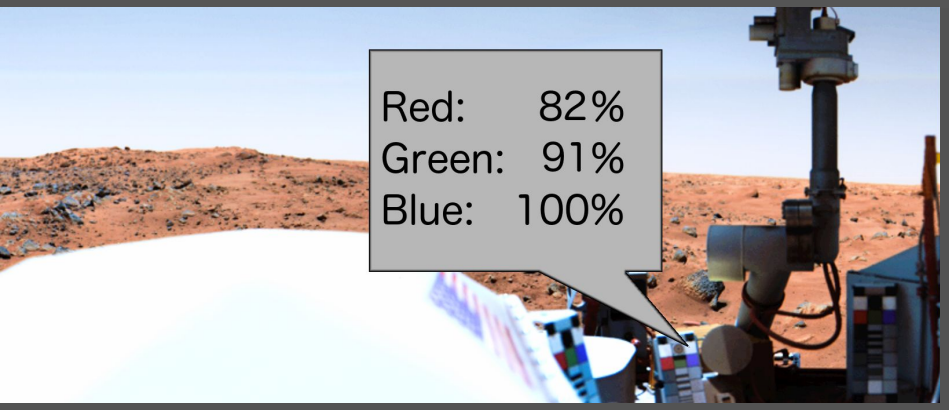


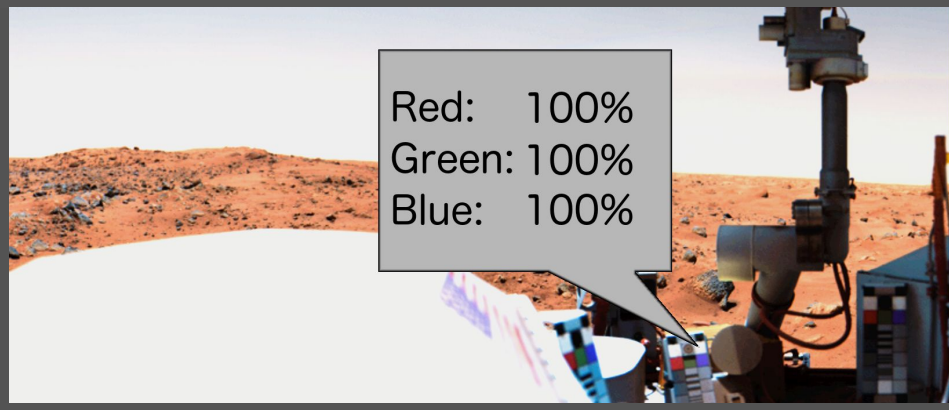
Viking Lander 1, 1976
Camera Profile applied
white balanced

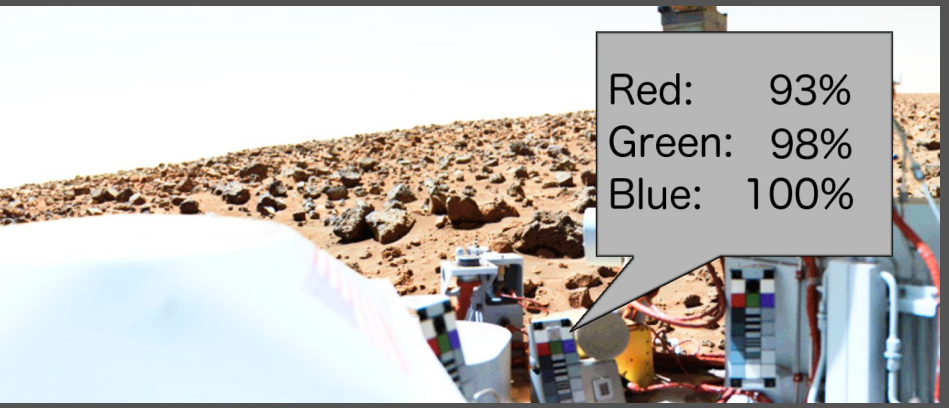
Viking Lander 2, 1976
camera profile applied
daylight setting = white balanced, only 7% diff.

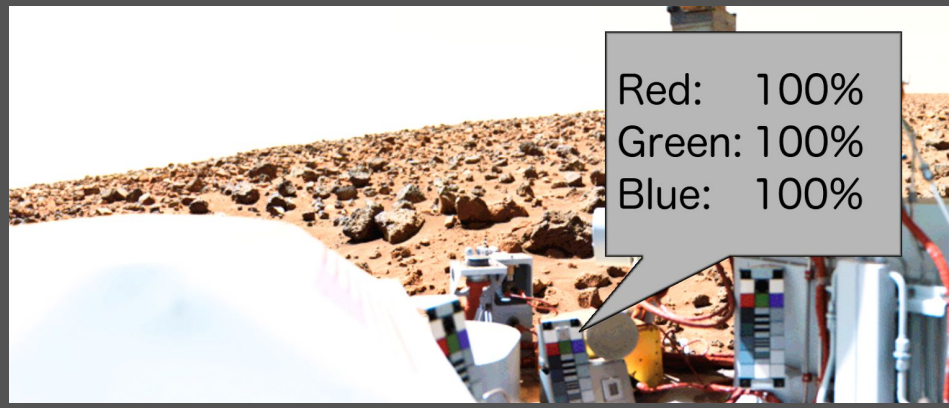
White Point during Clear Sky on Mars & Earth

daylight setting	white balanced



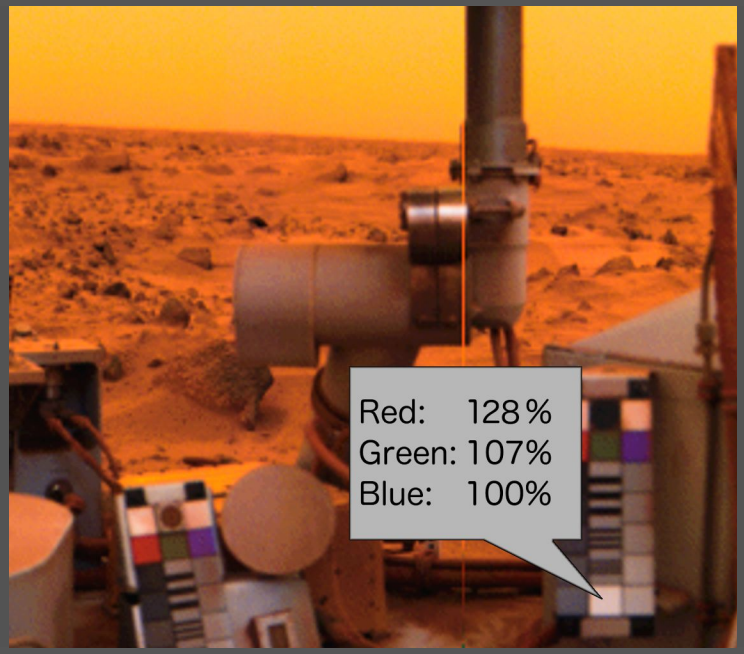




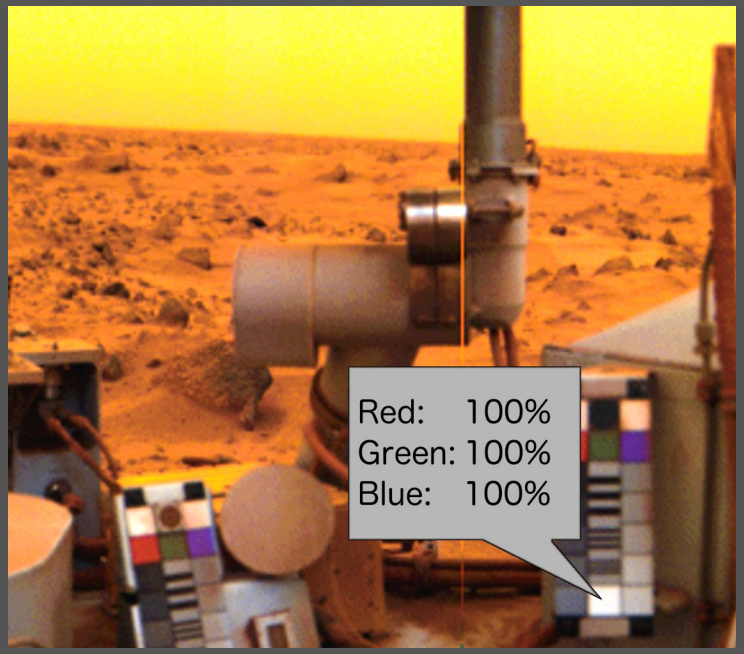


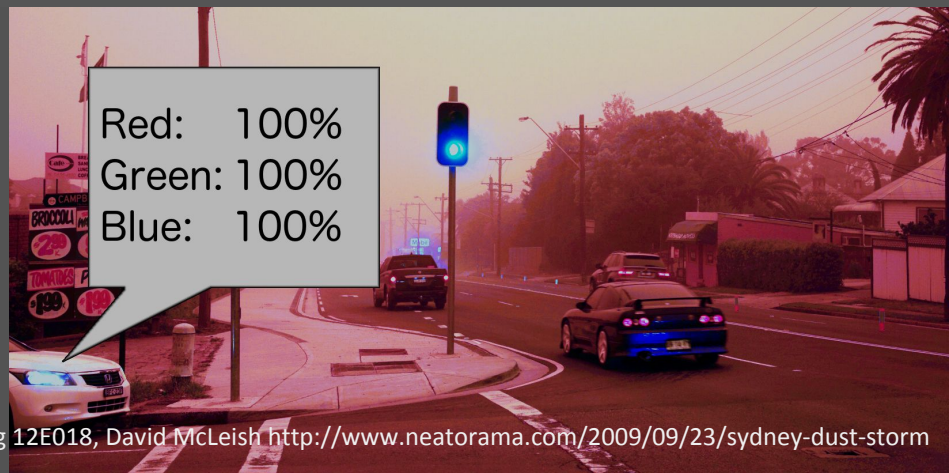
White Point during Dust Storm on Mars & Earth

daylight setting



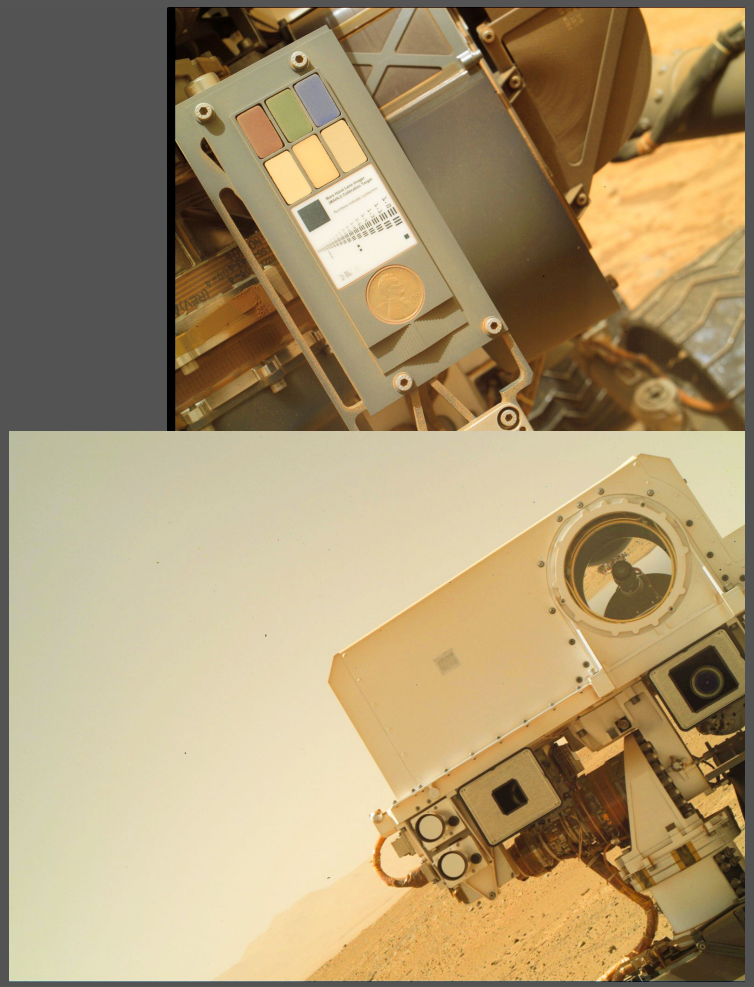
white balanced



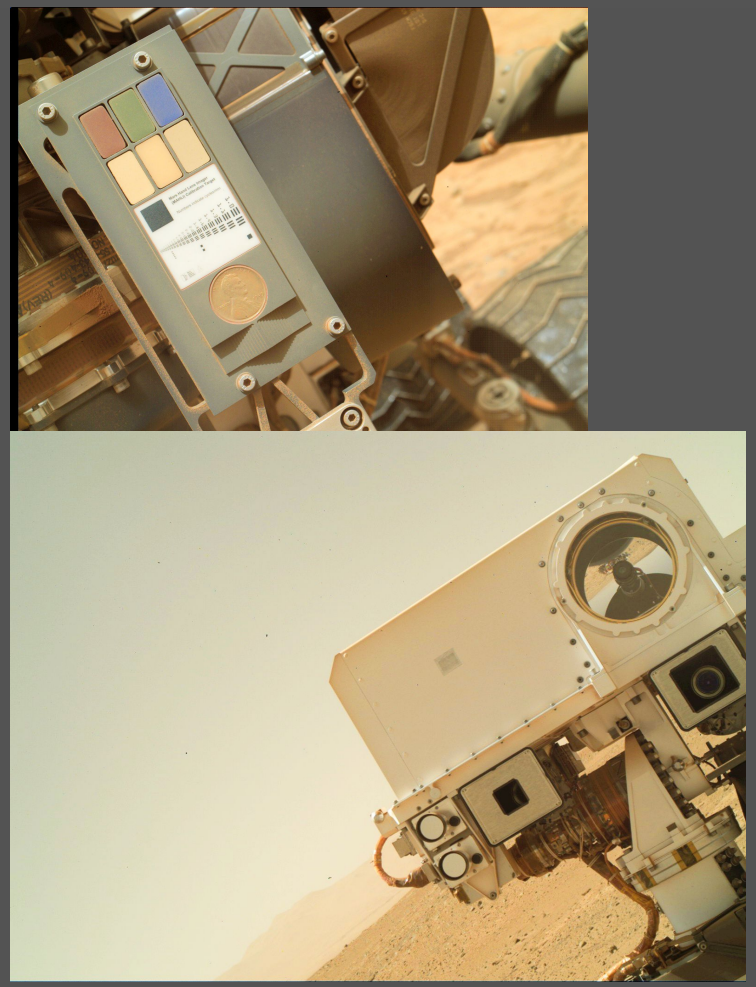


raw images: NASA / JPL / Viking 12E018, David McLeish http://www.neatorama.com/2009/09/23/sydney-dust-storm

2 Profile Creation Methods for MAHLI Camera
Barely visible differences

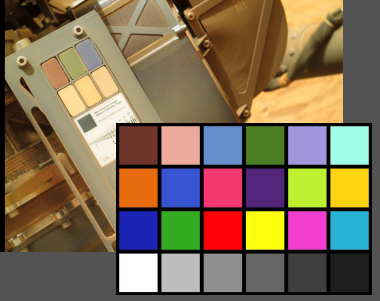
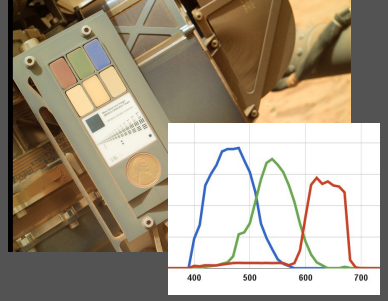


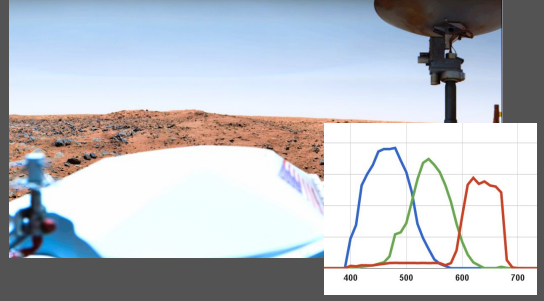
Profile from Reference Target

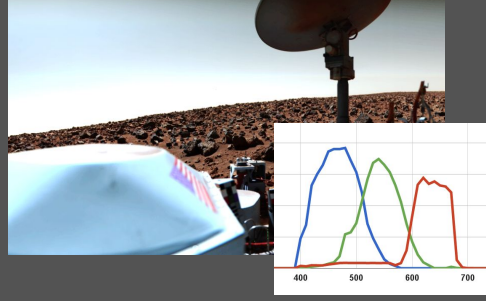


Profile from Spectral Sensitivity Functions (SSF)


Curiosity Rover, Sol 613
daylight setting
Panorama by Damia Bouic
Raw images: NASA / JPL
http://www.db-prods.net/marsroversimages
http://redplanet.asu.edu/?p=6574





Only imperceptible differences between:

3 Calibration Methods in clear sky conditions

- profile from ColorChecker24 photo
- profile from Spectral Sensitivity Functions
- application of white balance

2 Mars Missions

- Curiosity MAHLI 2012
- Viking Landers 1976, 4 cameras, 2 locations

Conclusions

- Same light conditions on Mars and Earth under clear sky near noon.

- No White Balance necessary.

- Applying a daylight camera profile replicates the experience a human observer would have.

- Mars colors are not alien.
  Colors and light conditions
  won't harm humans' well being.

Possible Error Sources

- straylight / background reflections in CC24 image
- light source measurement error for SSF
- software bug
- unusual non-continuous spectrum on Mars

Solutions for next Mars Rover

- take CC24 image in daylight with Mars camera
- take sample images in daylight with Mars camera
- place dust repelling ColorChecker24 on Mars
- white target visible for ChemCam Spectrometer

Practical Color Calibration For Mars Surface Images

Holger Isenberg
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holger.isenberg@gmail.com

Image: Viking Lander 1, 1976
calibration by Holger Isenberg