CREATING TRUE-COLOR IMAGES OF MARS FROM SPECTROMETER DATA. A. P. Karides, D. C. Humm, and F. P. Seelos, Johns Hopkins University Applied Physics Laboratory 11100 Johns Hopkins Rd, Laurel, MD 20723

Introduction: True-color images of the planet Mars are generated from spectral radiance data taken by the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) [1] on the Mars Reconnaissance Orbiter (MRO) [2]. CRISM covers the whole range of wavelengths seen by the human eye, sampled at ~6.5 nm, which allows accurate modeling of how a given CRISM scene would appear to a human looking down from orbit around Mars. These derived true-color images (e.g. Figure 3A) are quite different in appearance from CRISM visible wavelength visualizations presented in the existing literature, including the TRU (enhanced visible color) browse product [3] which is constructed from visible wavelength data but stretched to accentuate spectral variability (e.g. Figure 3B).

Process: The true-color spectral transform procedure makes use of CRISM Planetary Data System (PDS) standard product Targeted Reduced Data Record (TRDR) spectral radiance (RA) image cubes.

A CRISM hyperspectral Visible and Near InfraRed (VNIR) image cube has 107 channels from ~360 nm to ~1060 nm. However, only the wavelength bands between 380 nm and 780 nm affect human color perception as shown in the International Commission on Illumination CIE Color Matching Functions [4] (Figure 1). These functions show how much each component in the XYZ color space is affected by radiance as a function of wavelength. However, preprocessing of the both the CRISM radiance data and the CIE reference functions is required.

VNIR filter boundary correction. CRISM spectral radiance values at wavelengths from 631 nm to 710 nm are radiometrically unreliable due to an order sorting filter boundary [1]. To correct for this, a 2^{nd} order polynomial was fit to the 4 bands on either side of the boundary, and the interpolated values replaced the suspect values in the radiance spectra. This was done independently for every spatial pixel in the image.

CIE color matching function spline. The CIE Color Matching Functions are sampled every 5 nm [4] while CRISM VNIR data has a ~6.5 nm spectral sampling [1]. Therefore the CIE function for each of the three tristimulus values, X, Y, and Z was interpolated to the CRISM wavelength vector using a cubic spline. The resulting values were then buffered in wavelength to match the 107 channel CRISM spectral radiance data.

Creating the CIE tristimulus values. Each of the three interpolated and buffered CIE Color Matching Functions was multiplied by the radiance spectrum for each CRISM spatial pixel. This created a weighted image cube for X, Y, and Z. Newton-Cotes integration of the radiance-weighted X, Y, Z spectra was performed to arrive at the tristimulus 3-vector for each spatial pixel. These results were then compiled into an image cube with the vertical and horizontal dimensions equal to the input CRISM image and the tristimulus values in the third dimension.

Scaling to the capability of the monitor. Luminance in candela/m^2 is defined as 683 times the Y tristimulus value [5]. In order for the image to display on a computer screen with reasonably accurate brightness, each tristimulus value is multiplied by the typical monitor luminance, and then divided by the 3-sigma value of the Y tristimulus distribution (chosen to represent the maximum value while excluding errors) times 683. While this creates a proportional brightness image, it does not create a "true-brightness" image unless the monitor brightness exceeds that of the Mars scene.

Transformation into the sRGB colorspace. The sRGB colorspace is the standard colorspace originally for use on the internet [6]. For each pixel, the (X, Y, Z) vector of tristimuli bands was multiplied by a transform matrix to create the sRGB red, green, and blue values (Figure 2). The result is then adjusted for a 2.2 gamma correction [6] [7], and multiplied by 255 (from the hexadecimal color range) for 24-bit color specification. These values can then be used to plot each respective pixel color on the sRGB color space. Map-projected renderings of CRISM image FRT00003E12 of Nili Fossae are shown in true-color and false-color for comparison (Figure 3A, 3B).

Imagery Note: Any true-color image will not be truly accurate unless printed using a calibrated printer or displayed on a calibrated monitor. Images should not be viewed in any software that distorts color, contrast, or brightness.

References: [1] Murchie S. et al. (2007) *Journal of Geophysical Research*, 112. [2] Zurek R. W. and Smrekar S. E. (2007) *Journal of Geophysical Research*, 112. [3] Viviano–Beck C. E. et al. (2014) *Journal of Geophysical Research*, 119, 1403–1431. [4] CIE 15: Technical Report: Colorimetry, 3rd ed. (2004). [5] McCluney W.R. (1994) *Introduction to Radiometry and Photometry* [6] Stokes et. al. (1996) *A Standard Default Color Space for the Internet – sRGB, Microsoft and Hewlett-Packard Joint Report, Version 1.10* [7] Bell J. F. et al. (2006) *Journal of Geophysical Research*, 111. 3.2.

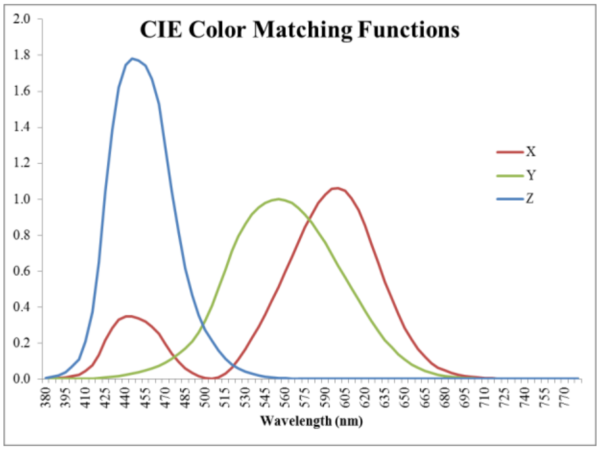

Figure 1 (above) CIE Color Matching Functions for each wavelength that affects color.

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 3.2406 & -1.5372 & -0.4986 \\ -0.9689 & 1.8758 & 0.0415 \\ 0.0557 & -0.2040 & 1.0570 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

Figure 2 (above) Transform matrix and operation that the X, Y, Z tristimulus values undergo to become part of the sRGB colorspace.

Figure 3B (below) CRISM image FRT00003E12 in enhanced visible color (false-color) created with one band each for red, green, and blue (R: 592 nm; G: 533 nm; B: 492 nm).

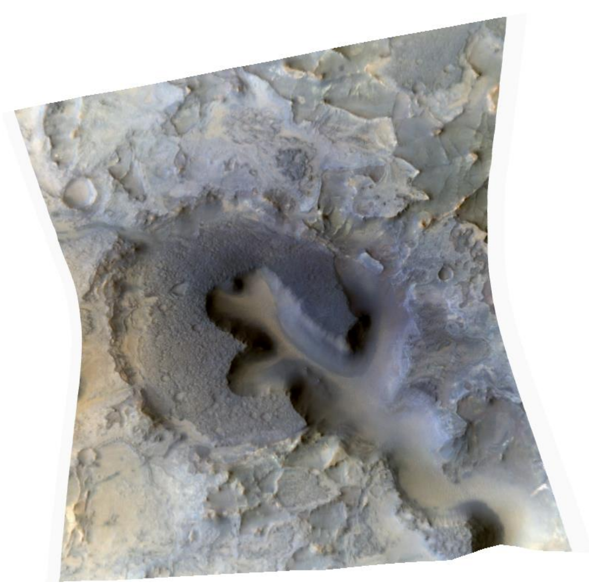

Figure 3A (below) CRISM image FRT00003E12 in true-color created through the process detailed in the abstract.