Can we use HiRISE color data to extrapolate Mastcam multispectral data beyond Curiosity's traverse?: Insights from Vera Rubin ridge, Gale crater, Mars. A. M. Eng[1], F. Rivera-Hernández[1], J. J. Wray[1], W. H. Farrand[2] [1]Georgia Institute of Technology (aeng60@gatech.edu) [2]Space Science Institute

Introduction: Constraining the composition and mineralogy of the martian surface is important for reconstructing the aqueous history of Mars. At the orbital scale, imaging spectrometers, like the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM), can reveal compositional information. However, CRISM targeted observations with the highest spatial and spectral resolutions (544 wavelengths at 0.4–3.9 µm, 18–36 m/pixel) only cover ~2-3% of Mars' surface [1]. Multispectral CRISM observations cover about 80% of Mars' surface but only at a spatial resolution of ~200 m/pixel [1], making refining geologic members difficult. In contrast, Pancam, Mastcam, and Mastcam-Z cameras provide multispectral observations at the outcrop scale but are limited to rock targets explored along a rover traverse at specific locations on Mars. However, these orbital and rover datasets can be supplemented with High-Resolution Imaging Experiment (HiRISE) color images that have 25 cm/pixel spatial resolution and cover ~3% of the surface [2]. While not a spectrometer, HiRISE color data is a complementary tool for mineralogy investigations (e.g., [3,4,5]) and due to its high spatial resolution is often used to study small scale geologic features such as stratigraphic contacts (e.g, [6]). Previous studies have used HiRISE color to extrapolate CRISM observations to areas without CRISM coverage (e.g., [7,8,3]). Here we explore whether HiRISE color data can similarly be used to extrapolate Mastcam multispectral observations beyond the *Curiosity* traverse. This may enable extrapolation of not only spectral information at the sub-meter scale, but also textural and geochemical information from other rover instruments.

Methods: Here we focus on preliminary results comparing HiRISE color data to Mastcam multispectral observations acquired from sols 1734-2788, when *Curiosity* explored the lower Mount Sharp Group and the Siccar Point Group in Gale crater. This part of the traverse encompasses Vera Rubin ridge (VRr) and the surrounding geologic units. VRr in the Mount Sharp Group is rich in iron-oxides and is hypothesized to have gone through extensive diagenesis [9]. The primary control on Mastcam multispectral variability is the presence of iron oxides [10], thus VRr is an ideal location to test our methodology.

HiRISE bands BG, Red, and IR were loaded into ENVI to extract color data from the three bands. Regions of interest (ROIs) were acquired on HiRISE observations limited to emission angles < 30 degrees, incidence angles <50 degrees [11], and optical depth measurements under 0.6 recorded by the *Curiosity* rover [12] to limit photometric and dust effects, respectively. We chose homogenous areas near rover waypoints for HiRISE ROIs of at least 100 pixels, and the color data was extracted from each pixel. Radiometrically calibrated HiRISE data has an error of about 20% [13]. The pixel values can be converted to I/F using the following equation:
I/F = (PIXEL_VALUE * SCALING_FACTOR) + OFFSET [13]. Mastcam is a stereoscopic imaging instrument with a pair of cameras at two different focal lengths, which can collect reflectance data at 12 wavelengths from 445 nm to 1013nm. The spectra are extracted by averaging the pixel values in an ROI. Multispectral observations are regularly acquired on surfaces subjected to the Dust-Removal Tool (DRT). We use spectra from dust-removed rock and dusty counterparts from [14] and [15] to discern which results in a closer match to HiRISE color data.

Preliminary Results: The HiRISE bands are often highly correlated with one another. Like previous studies (e.g., [5]), we plot the BG/Red ratio against the IR/Red ratio. Since the transmission profiles of the HiRISE bands are much broader than those of Mastcam, we had to identify which Mastcam filters were best suited for our comparison. By testing out different combinations of Mastcam filters within the HiRISE transmission profiles, we found that the Mastcam filters L1 (527 nm), L4 (676 nm), and L5 (867 nm), produced results closest to those of the HiRISE bands (Figure 1). Not surprisingly, these Mastcam filters are near the centers of the HiRISE transmission profiles.

Across both instruments, the data can be divided between red and blue surfaces (Figure 1). The IR/Red and 867 nm/676 nm ratios are controlled by electronic iron absorptions and show common ranges between instrument datasets (Figure 1). The BG/Red and 527 nm/676 nm ratios, however, have different ranges of values between datasets. This is attributable to the dust that is inevitably included in HiRISE ROIs, increasing the red slope between ~500 and ~700 nm. There are some similarities between datasets. Blunts Point shows some of the smallest HiRISE IR/Red and BG/Red ratios, and the Mastcam equivalents. Glasgow and Gray Jura show higher BG/Red and 527 nm/676 nm ratios, with Glasgow having a few targets with smaller 867 nm/676 nm ratios like the HiRISE data (Figure 1). Data from Red Jura, Pettegrove Point, and Knockfarril Hill show ratio values characteristic of red surfaces (Figure 1). Dust has been proven to dampen or mask spectral absorptions, which may explain why a few Mastcam dust-removed rocks have larger IR/Red ratios than their HiRISE counterparts. The only area with data that are not generally consistent between instruments is the Greenheugh Pediment, where the spectra from Mastcam ROIs on dust-cleared rocks are much bluer than the color data extracted from the HiRISE ROIs (Figure 2). Thus, whether HiRISE color data reflects dusty or dust-cleared rock is dependent on a "dust-threshold" component that is likely different across geologic units. This cross-instrument analysis may be useful in making qualitative conclusions on the amount of dust present.

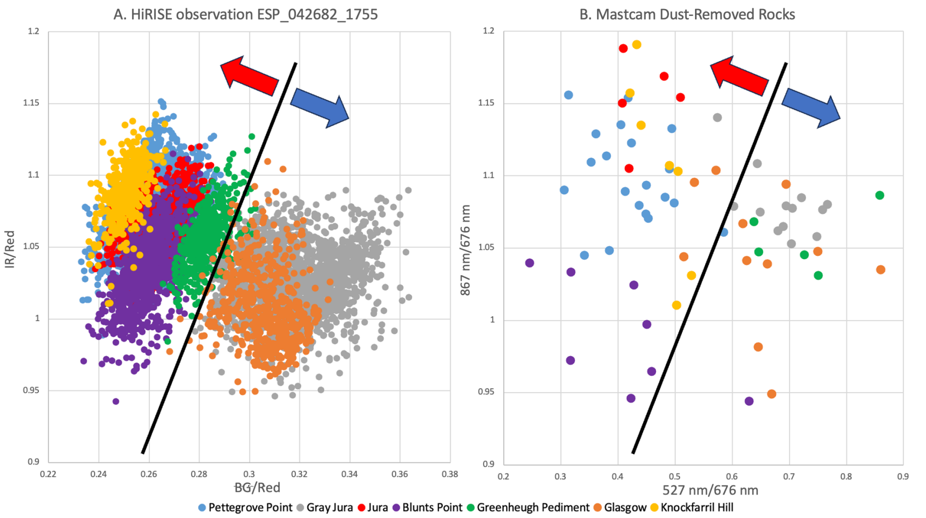

Figure 1: A. HiRISE color data per pixel in an ROI and B. Mastcam multispectral data from averaged ROIs on dust-removed rocks. The line and arrows highlight the parameter spaces that characterize red and blue surfaces, as observed from orbit and the rover mast, respectively.

Future Work: In future work, we will collect multispectral data from Mastcam ROIs that are approximately the size of a HiRISE pixel (25 cm x 25 cm), in attempt to more accurately capture what HiRISE does. Then, we will perform covariance analyses between HiRISE color data and Mastcam multispectral data from (1) dusty rock ROIs, (2) dust-cleared rock ROIs, and (3) HiRISE-pixel-sized ROIs. This will be done for reflectance data from Mastcam filters in this study and for the averages of data from Mastcam filters that fall within each HiRISE band transmission profile (i.e. for HiRISE Red, average together the Mastcam filters that are between 570 and 830). In addition to Mastcam, ChemCam passive data may also help inform our analyses by exploring different ratios and band depths to compare to orbital data as performed by [16].

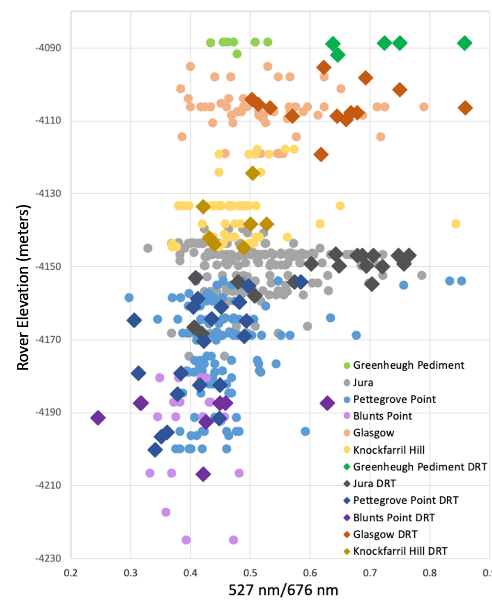

Figure 2: A comparison of the 527 nm/676 nm ratio from Mastcam spectra of dusty rocks (circles) and dust-removed rocks (diamonds)

References: [1] Seelos et al. (2023) Icarus [2] McEwen et al. (2023) Icarus [3] Bennet et al. (2012) LPSC [4] Scheller and Ehlmann (2020) JGR [5] Dapremont and Wray (2023) Icarus [6] Anderson and Bell (2010) Mars 5 [7] Seelos et al. (2011) AGU [8] Sacks et al. (2020) LPSC [9] Horgan et al. (2020) JGR [10] Rice et al. (2022) JGR [11] Fernando et al. (2017) LPSC [12] Lemmon et al. (2024) Icarus [13] Delamere et al. (2010) Icarus [14] Rice et al. (2022) Western CEDAR [15] Eng et al., 2023 Western CEDAR [16] Fraeman et al. (2020) JGR