AUTHENTIC SCIENCE AND ENGINEERING PRACTICES THROUGH THE MARS EXPLORATION ROVER IMAGING PROJECT.

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Introduction: Since the release of the NGSS [1], K-12 teachers have become increasingly aware of the need to engage students in science and engineering practices. However, the resources to enact such engagement in authentic ways are scarce. Through a collaboration between JPL and Mars Exploration Rover team scientists with Centaurus High School instructors, the "MaRTIAn" (Mars Rover Teams Imaging and Analysis) program engages students in authentic science and engineering practices. The experience includes students developing research questions, analyzing Mars rover image data, and developing evidence-based conclusions to research questions.

The NASA/JPL Mars Exploration Rovers (MER), Spirit and Opportunity, were launched in 2003 to explore two scientifically compelling areas on Mars [2,3]. In so doing, many young scientists and engineers were trained in the techniques to work as a group on the instrumentation, geological research, software tools and engineering research to explore another planet. In 2014, John Callas, project manager of the Mars Exploration Rover Project at NASA's Jet Propulsion Laboratory envisioned a project whereby high school students could use the 13 geology filters of the "Pancam" camera [4] on the MER rover "Opportunity" to answer a scientifically relevant question they have about the geology on the surface of Mars where Opportunity is exploring. NGSS specifies that students will engage in science and engineering practices (carrying out investigations, analyzing and interpreting data, etc.), and this is a rare opportunity for high school students to experience current scientific and engineering practices.

With the NGSS in mind, we went about developing an extracurricular project where students at Centaurus High School in Lafayette, CO (Grades 9-12) could participate with the rover science team and explore Mars and in so doing, apply their science and engineering coursework in a way that was inspiring, authentic, and goal oriented. We developed an organization for the student-oriented group that mirrored the MER "Science Operations Working Group" (SOWG) for rover operations. For much of this project, students placed themselves in groups based on a science theme (geology, spectroscopy, atmospheres) or on an instrument (photometer, multispectral camera) as well as software theme group to develop "data products" (**Fig. 1**), a website group, a map group, etc. Each group is researching background information about their science or instrument, and able to use that to contribute to the group's science question, analysis and/or conclusions.

Fig. 1. Analysis software student group assessing the annotated image they developed.

Initially, students worked together to develop the "MaRTIAn" Acronym (Mars Rover Team Imaging and Analysis) as the name of their group along with a logo (**Fig. 2**) that showed the rover and a rainbow emanating from the Pancam to show that they do spectral analysis.

Fig. 2. MaRTIAn team logo.

The entire group was briefed by MER science team member Farrand on the MER mission goals, spacecraft and Martian geology that scientists on a variety of planetary missions have determined so far. Students were trained in the science decision making processes employed by the MER SOWG teleconferences using a set of training videos and corresponding worksheets. MER Program Manager, John Callas, with JPL staff, provided video recordings of an actual SOWG meeting so that students are able to participate with the SOWG group during a teleconference to discuss their experimental ideas, specific images requested from the rover and their analysis and results.

Dr. William Farrand, Space Sciences Institute and member of the MER science team is working with CHS students in their endeavors. Dr. Farrand has met with the high school students and discussed the mission of the Opportunity rover, Mars' geologic history as well as the image processing techniques used to determine the mineralogy of rocks. Both the spectroscopic data and the morphological data inform the science team about rock identification and geologic processes that have occured on the surface of the planet.

The Centaurus High School "MaRTIAn" science team (**Fig 3**) has been preparing for their experiments on the surface of Mars for over a year. They have explored the use of the Pancam instrument in atmospheric opacity study of the Martian dust, a student built a photometer to be able to add atmospheric data from our location on Earth to a GLOBE database. So far, there have been two engineering projects around building a multispectral camera using narrow bandpass filters to produce multiple images of a scene, gathered in a set of distinct bandpasses. A software group, led by Samuel Estrella, has developed a way to take spectral information from the several images and compare each pixel on the hyperstacked images to determine common mineralogy (**Fig 1**).

Students are developing a website to be able to share our ideas, training and results from our analysis of images of the Martian surface with other students.

Fig. 3. MaRTIAn team on a tour at the University of Colorado LASP lab.

We hope that through a website, other high school students groups around the country can build their own "MaRTIAn" science group and explore science and engineering processes with the Opportunity rover, and future rovers operating on another planet. Individual students often go on to college and build on what they've learned with the MaRTIAn group, most of whom are in STEM fields, many in Aerospace Engineering or planetary science.

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