VIRTUAL AND AUGMENTED REALITY TOOLS FOR PLANETARY SCIENTIFIC ANALYSIS AND PUBLIC ENGAGEMENT. A. Bahremand[1], L. Gold[1], C. Richards[1], K. Sese[1], K. E. Powell[2,3], S. Dickenshied[2], S. Anwar[2], J. R. Hill[2], C. S. Edwards[3], R. LiKamWa[1,4], [1]School of Arts, Media & Engineering, Arizona State University, [2]School of Earth & Space Exploration, Mars Space Flight Facility, Arizona State University, [3]Dept. of Astronomy & Planetary Science, Northern Arizona University, [4]School of Electrical, Computer & Energy Engineering, Arizona State University.

Overview: Our teams are building new tools for integration and analysis of 3D planetary data in augmented reality (AR) and virtual reality (VR) environments. Our goal is to provide functionality that will spur scientific discovery through seamless presentation of multiple co-registered datasets. Our first project [1] enables the user to experience a full-scale first-person perspective while simultaneously viewing orbiter spectroscopic data over the same area. In a subsequent project, we have implemented an extension to the JMARS application [2] to add both AR and VR views, making a myriad of data products available and accessible.

Orbital + Ground Mars VR: With this project we seek improved methods to integrate data in areas on Mars where both ground-based and orbital-based data sets are available, allowing interpretations of chemistry and mineralogy to be made at the same location with different spatial scales. We focus on the Curiosity rover traverse in Gale Crater towards Mt. Sharp as an area with an abundance of data and high utility due to the ongoing mission.

In this application the user traverses the surface of Mars at 1:1 scale by using a VR headset. Meanwhile, the location of an overlying pixel from the CRISM instrument is indicated by a polyhedron covering the location and shape of a pixel and its intersection with the 3D surface. The current interface allows the user to teleport across the terrain and manipulate the pixel block along the rover's traverse. Multiple spectra from multiple pixel blocks can be recorded for comparison.

We are continuing to build meshes to cover the complete Curiosity traverse (in the timeframe with publicly released data). In the future, we plan to integrate other data sets, including Curiosity chemical and mineralogical data from Mastcam, ChemCam, and APXS, and orbital data including HiRISE and THEMIS.

JMARS in AR/VR: The Java Mission-planning and Analysis for Remote Sensing (JMARS, http://jmars.asu.edu), developed at the Mars Space Flight Facility at ASU, provides access to a variety of co-registered orbital datasets. Users can download JMARS to personal computers at no cost. Data is available for all the major planets and a number of asteroids and small bodies, including digital elevation models (DEMs) and 3D global models. Any other data set can then be draped over this 3D data and viewed in a separate 3D window, allowing the user to easily correlate morphology with compositional or physical parameters of the surface derived from these instruments.

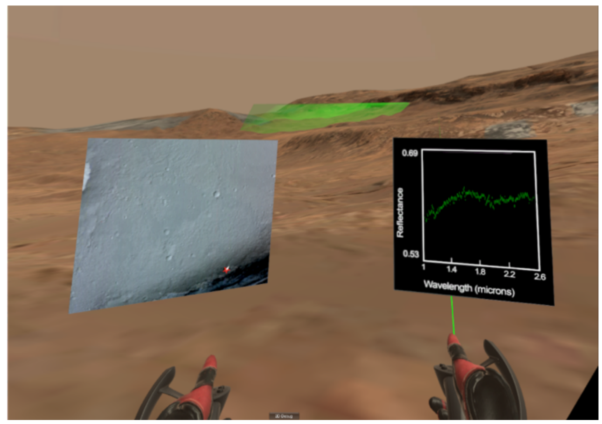

Figure 1: This VR environment provides the user with a first-person perspective on Curiosity rover images. The green polyhedron represents the intersection of an orbital CRISM pixel footprint with the 3D surface. The user's other displays include a local map of the rover's traverse for navigation, and a plot of CRISM spectroscopic data corresponding to that pixel.

In this work we leverage the existing 3D functionality and extended it to include both AR and VR interfaces. JMARS includes access to a large number of datasets that have previously been co-registered. In the AR view, a smartphone or tablet may be used to project any JMARS product onto a flat surface using a printed marker. Multiple users may then view the same content in 3D, on the same or multiple screens. Alternatively, a single user equipped with a VR headset can explore the terrain while other users watch their perspective on a connected computer monitor. This implementation opens up new possibilities for conversation and collaboration between researchers. Either method allows collaborative work without the requirement of obtaining multiple expensive headsets. The use of existing JMARS servers allows the user to navigate dynamically without the burden of pre-downloading large image files into a new application.

Outreach Applications: Although our current frameworks were designed with researchers in mind, they also lend themselves well to public outreach experiences. One such experience has been created for an ASU Arts Media Engineering undergraduate capstone project; the students took a single Curiosity site from the orbital/ground Mars VR project and augmented it with imaginative content based on the concept of future human explorers visiting the Curiosity site.

We also envision creating JMARS content that is pre-packaged for the student or adult science enthusiast experience. Users would be able to load pre-created experiences on their smartphone simply by following a link to download a standalone application from the iOS or Android store. This could provide educational experiences utilizing existing frameworks, while removing barriers to using JMARS resulting from lack of access to technology or needing significant experience to explore data sets.

References: [1] Powell K. E. et al. (2019) *LPSC* L, Abstract #1459. [2] Christensen, P.R.; Engle, E.; Anwar, S.; Dickenshied, S.; Noss, D.; Gorelick, N.; Weiss-Malik, M., AGU 2009, Abstract IN22A-06.

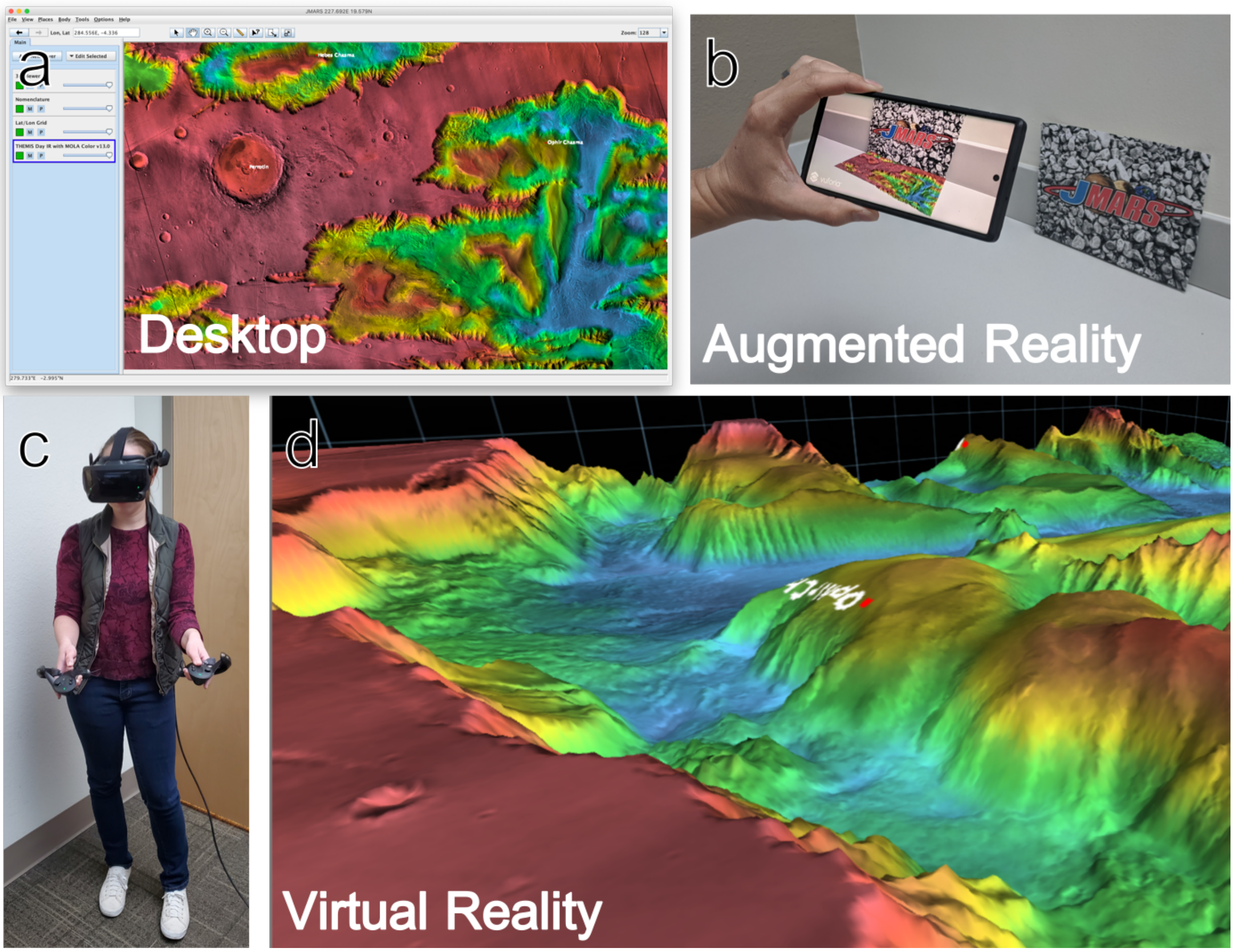

Figure 2: JMARS in its standard application view and in AR and VR. a) A desktop user's view of Ophir Chasma, Mars (-72°E, -4°N) and surrounding terrain. Data displayed is THEMIS daytime IR overlaid on and colorized with MOLA elevation. b) An AR user's view of the same scene, projected in front of them on a tabletop surface. c) A VR user viewing the terrain using a headset immersing them in the terrain. D) The same headset view displayed on a computer monitor. All topography is 3x virtually exaggerated.