DEVELOPMENT OF A CITIZEN SCIENCE APPLICATION TO MAP AND CLASSIFY ROCKS ENCOUNTERED ALONG NASA'S VIPER TRAVERSE. D. M. Krum[1], A. N. Deutsch[2,3], A. Colaprete[2], B. Day[4], K. Ennico-Smith[2], C. Fassett[5], E. Law[6], E. Kang[1], S. Malhotra[6], U. Wong[2], E. Noe Dobrea[2], M. Chin[2], E. Talle[2], S. Gyalay[2,7], J. Pineda[1], K. Andrade[1], D. Arteaga-Andrade[1], S. Bautista[1], M. Gibson[1], C. Gomez[1], N. Sheikh[1], Z. Sulaiman[1], D. Tabilas[1], A. X. Ujpan[1], T. Xaypraseuth[1], [1]California State University, Los Angeles, [2]NASA Ames Research Center, Moffett Field, CA, [3]Bay Area Environmental Research Institute, Moffett Field, CA, [4]NASA SSERVI, Moffett Field, CA, [5]Johns Hopkins Applied Physics Laboratory, Laurel, MD, [6]Jet Propulsion Laboratory, Pasadena, CA, [7]SETI Institute, Mountain View, CA.

Introduction: *VIPER Rocks!* is an exciting web-based application in development to allow citizen scientists to enhance the science return of NASA's Volatiles Investigating Polar Exploration Rover (VIPER) mission, scheduled for launch to the Moon in late 2024 [1]. On this website, citizen scientists will map, measure, and classify rocks encountered during VIPER's traverse, as imaged by the rover's cameras.

VIPER Rocks! is a collaboration between the VIPER Science Team, California State University, Los Angeles (CSULA), NASA's Solar System Treks Project (SSTP) Team, and NASA SSERVI. Rock size and shape-classification software tools are being developed as a CSULA undergraduate computer science Senior Capstone project, and integrated into NASA's established SSTP Moon Trek data visualization and analysis portal (https://trek.nasa.gov/moon). The SSTP Team at JPL is helping to build and test *VIPER Rocks!* prior to it being rolled out to a diverse population of citizen scientists who will conduct initial user testing and provide the foundation for subsequent citizen science classification of VIPER mission images.

***VIPER Rocks!* Science Objectives:** Analyses of lunar polar rock populations and global comparisons between VIPER-explored polar terrain and previously roved non-polar terrains will enhance the science return of the VIPER mission while providing useful information about the lunar surface for future exploration (**Fig. 1**).

Science Objective 1: Determine rock size-frequency distributions (FDs). Rock size-FDs provide information about the ages, exposure history, and maturity of the surface [2–4]. Those derived from citizen scientist measurements will be used to estimate relative ages of landscapes imaged by VIPER [4–6] and to provide insight into the thermal and physical processes driving the breakdown of rocks at the lunar poles [2–8]. Additionally, the rock size-FDs derived from in-situ measurements will provide important metrics for site analysis and hazard assessment for future surface exploration [8–11].

Science Objective 2: Determine rock shape-frequency distributions. Rock shape-FDs provide important insight into how surface materials structurally degrade and will be used to analyze variations in rock shape as functions of distance from craters and surface temperature to investigate physical and thermal processes shaping the surfaces [3, 4, 14–16]. Assessing shape information will provide important insight into how VIPER-observed materials break down in the polar environment, allowing comparisons between polar and non-polar surfaces [10, 12, 13, 17, 18].

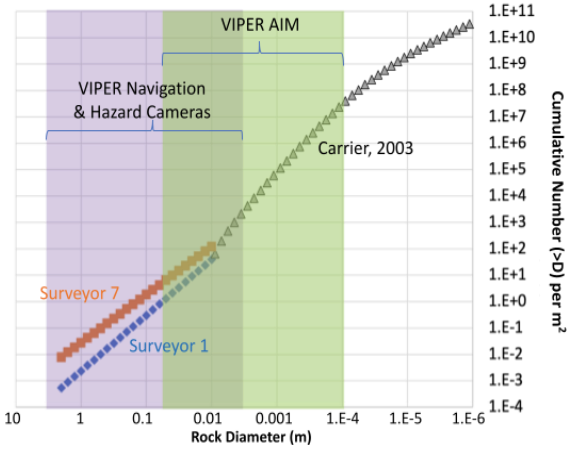

Figure 1. *Low-latitude lunar rock size-FDs using Surveyor data [12] and Apollo samples [13]. The VIPER cameras will enable the first high-latitude lunar size-FDs over four orders of magnitude in spatial scale.*

Technical Approach: *Citizen scientist tasks.* Citizen scientists will perform three primary tasks within *VIPER Rocks!*: (1) scouting for rocks to help partition workload evenly within the classification tasks, (2) measuring rocks to provide dimensional data, such as rock diameter, and (3) classifying rock shapes by matching rocks to a standardized scale that spans from rounded to angular shapes. The User Interfaces (UIs) for these tasks will balance precision, accuracy, and throughput. While precision and accuracy help improve classification quality, time-consuming tasks reduce throughput as users become fatigued. Specific tradeoffs and UI prototypes are being designed and evaluated by the CSULA student team and SSTP team. Classifications from individual users will also be aggregated and compared by the system to provide inter-rater reliability metrics to help identify images for

additional review or classification, and to provide feedback for more consistent classifications.

Collection of test data. We recently created a test image dataset while imaging lunar highland simulant [39-40] and anorthosite rocks with spare VIPER cameras inside the SSERVI Lunar Regolith Testbed at NASA Ames (**Fig. 2**). Anorthosite rocks were broken up and shaped in a rock tumbler so that the test images provided a range of rock sizes (mm to dm) and shapes (more rounded to more angular) for development and testing of the *VIPER Rocks!* tools. Images were collected under conditions (e.g., illumination geometries, spatial scale) similar to those that VIPER is expected to encounter at the south pole. These VIPER test images are being used in conjunction with Apollo and Chang'e surface images, which are included as standards in the test set to evaluate beta testing performance (see below).

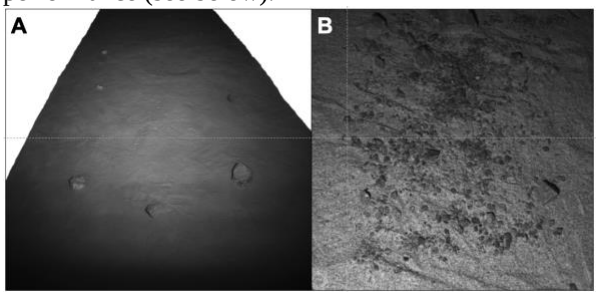

Figure 2. (A) VIPER NavCamLeft image of testbed, acquired ~2 m above surface with tilt angle of ~40° with navlight on (width of testbed ~4 m). **(B)** VIPER 540-nm AIM test image (frame ~22.5 cm across).

System overview. We are leveraging NASA's SSTP Moon Trek architecture and developing custom UIs and backend infrastructure to support VIPER imagery, metadata, and subsequent citizen science classifications. There will be a database of images and metadata, interfaces for various rock measurements and classifications, a protected user database for citizen scientist user accounts, and functionality for statistics and reports. Interaction and user-experience designers are working to ensure citizen science tasks are appropriately sized in terms of duration and difficulty. The web app will provide comprehensible explanations of the *Viper Rocks!* project and the importance of citizen science contributions with clear training examples, easy-to-use UIs, and feedback on the scientific results and understanding gained. The app design will also follow standard web usability and data protection regulations. The system will also use rewards and other motivations such as badges, teams, competitive matchups, and messages from VIPER scientists to encourage and sustain citizen scientist participation. Motivations will be designed and evaluated as appropriate for a broad range of ages and experience.

Beta testing. During beta testing, user experience and scientific output will be evaluated and validated. A target of >50 beta testers will be recruited from existing relationships with citizen science groups representing a range of ethnic and socio-economic communities, and will include experienced amateur astronomer citizen scientists, college students, and K-12 students. Twenty percent of beta testers will have experience with planetary science data.

To validate the scientific output of the beta testers, Apollo and Chang'e surface images will be included as standards in the test set, as mentioned above. Because the sizes and shapes of rocks imaged in these standards have previously been classified by lunar scientists [10, 12, 13, 17, 19], beta tester and expert classifications can be compared, which, along with data variance statistics for each task, will help track variability in beta tester performance.

Conclusions: In preparation for NASA's VIPER mission to the south polar region of the Moon [1], we are building a citizen scientist app within Moon Trek called *Viper Rocks!*. Previous and current citizen science efforts in planetary science such as Moon Zoo, MoonDiff, Cosmoquest's Moon Mappers, OSIRIS-REx's Bennu Mappers, and the Zooniverse AI4Mars project have successfully demonstrated the value of having citizen scientists discern, identify, categorize, and annotate planetary surface features returned from spacecraft data [e.g., 20–22]. In addition to enhancing the science return of NASA missions, citizen science efforts have been shown to increase public engagement.

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