MOON ZOO: UTILIZING LROC LUNAR IMAGES FOR LUNAR SCIENCE AND EDUCATION. K. H. Joy[1], C. J. Lintott[2], A. M. Smith[2], P. Gay[3], D. Roberts[4], L. Fortson[4] and the Moon Zoo Team[5].[1]UCL-Birkbeck Research School of Earth Sciences, Gower Street, London, WC1E 6BT, UK, (k.joy@ucl.ac.uk). [2]Oxford University, Oxford, UK. [3] Southern Illinois University Edwardsville, USA. [4]Adler Planetarium, Chicago, USA. [5]The other members of the Moon Zoo Team are identified in the Acknowledgments.

Introduction: Moon Zoo will be an online lunar citizen science project. It is one of several initiatives inspired by the highly successful Galaxy Zoo project (http://www.galaxyzoo.org/), which harnesses the power of the Internet to classify galaxies in support of astrophysics research. Using data provided by the project, the Galaxy Zoo science team was able to prove that classifications carried out by members of the public were as good as those accomplished by professional astronomers. Numerous papers have been published [e.g. 1-4] using the Galaxy Zoo database to address key questions about the formation and evolution of galaxies and to follow up on serendipitous discoveries of new and unusual celestial objects made by Galaxy Zoo users. The second Galaxy Zoo project (Galaxy Zoo 2) was launched in summer 2009, and within the first six months of operation it has received over 50 million individual classifications from the 250,000 people registered as Galaxy Zoo users.

The Moon Zoo Concept: Due to be launched in Spring 2010, Moon Zoo will be a similar online citizen science project that will ask users to identify, classify, and measure the shape of features on the surface of the Moon using a specially designed graphical interface (Fig. 1). The interface will be available in several languages to ensure the international appeal of this project.

Moon Zoo Data: The project will utilize released Planetary Data System (PDS) high spatial resolution images (with associated metadata) from NASA's Lunar Reconnaissance Orbiter Camera (LROC) instrument, which has been orbiting the Moon since June 2009. Statistical analysis of the Moon Zoo user data will allow us to address interesting lunar science topics, and will also aid the planning of future exploration of the Moon by robotic and manned missions.

Moon Zoo Science Goals: The Moon Zoo team has identified four preliminarily Moon Zoo user projects [6, 7] that can be readily addressed by registered Moon Zoo users utilizing LROC data. These projects address a variety of important lunar science and exploration themes [8], and are briefly described below:

Project 1. Statistical populations survey of small craters. This project has been subdivided into two smaller tasks:

Project 1a. To count the number and measure the dimensions of impact craters on the Moon (yielding both crater diameter and ellipticity) with the aim of improving the precision of small lunar crater population statistics. Crater counting allows us to calculate the apparent age of the lunar surface by comparing the number of impact craters on different lunar surfaces (i.e. lava flows, basin impact melt sheets etc.). Technical issues such as classifying primary vs. secondary craters are beyond the scope of user classification tasks and so they will form an important component of subsequent database exploitation and scientific interpretation. Understanding the age of different lunar lava flows and crustal surfaces will shed new light on the temporal thermal and magmatic history of the Moon, and it will have important implications for understanding thermal processes (or dynamics) of small rocky planetary bodies.

Other science goals include identifying small, highly elliptical impact craters that may have preferentially preserved meteoritic material [9] and producing maps of crater degradation states (see section about Validation below). The database will have several further uses. For example, the location of craters can be used to develop a control net of lunar crater location to help cartographic database and improve the lunar coordinate system. Additionally, we envisage that the results of citizen science crater dimension studies might be compared with automatic computer algorithm methods to assess the capabilities of automatic counting systems and citizen science efforts.

Project 1b. Users will also be asked to assess scales of blockiness state (ejected boulder concentration) of crater rims, to classify them and help to determine local regolith thickness variations [10].

Project 2. Users will assess the degree of boulder hazards across the lunar surface by comparing two images (of similar scale and similar illumination conditions), and identifying the one with the higher boulder density. These results will produce relative boulder-density hazard maps to help identify the most suitable locations for sending future robotic and manned missions to the Moon.

Project 3. Identify recent (in the last 40 years) changes on the lunar surface by comparing new LRO images with older Lunar Orbiter and Apollo photographs (of similar image resolution and illumination conditions). We hope to identify the locations of recent impact craters or landslides or even recent volcanic out-gassing centers on the lunar surface [11, 12]. By counting the number of 'new' impact craters we can calculate the current impact flux rate of the Earth-

Moon system [8], which is of great interest for assessing the risk to humans from asteroid and meteoroid impacts and also helps to constrain planetary chronology based on impact crater counting.

Project 4: We will also ask Moon Zoo users participating in both Project 1a and 1b to identify, and therefore catalogue, the location of interesting lunar features such as lava channels (rilles), volcanic eruptive centers (pyroclastic deposits), crater chains, bench craters, and bright fresh rayed craters within the scale size of the LROC image. We hope that members of the wider lunar science community will then be able to utilize this database to aid their own research objectives.

Moon Zoo Status:

Web Interface: GUIs for Project 1, Project 2 and Project 4 tasks have been developed using Flash software for the main classification interface (Fig. 1).

API/database: The Moon Zoo software API and database layer have been developed by the team at Oxford University, based on their experience with storing and analyzing large amounts of citizen science data.

Validation: The Galaxy Zoo project utilizes a variety of statistical analysis tools to study the quality of user classifications (i.e. how often they get the 'correct' answer compared to an expert classification; how varied the classification result is between users; identification of potentially malicious classifications etc.). Similar tools will be employed for exploiting the Moon Zoo user databases.

A variety of data reduction techniques will be employed to turn raw data collected by the Moon Zoo website into science-ready outputs. For example, it is possible to 'weight' users according to their level of agreement with professional classifications (or other results), and then iterate these results through the database. This technique has proved to be effective in obtaining high fidelity results even for apparently difficult citizen science tasks [1-4].

We also expect the validation process to produce additional science results; for instance, analysis of the standard deviation of the crater diameter histogram can help to reveal craters with degraded rims through slight variations in user measurements, because these will be the most difficult to measure.

Outreach and public engagement: Lunar science outreach information and links on the Moon Zoo website are being developed at SIUE under a NASA ROSES grant*. The Moon Zoo team is also working closely with Adler Planetarium to promote the project through their 'Moon Wall' interface and other outreach activities, and the NASA Lunar Science Institute as part of their lunar science education programme.

Concluding Statement: All new Zoo projects must be capable of delivering peer-reviewed science. Moon Zoo is poised to do just this by providing high quality data to address key questions in lunar science. At the same time, Moon Zoo will be an excellent education tool to help promote lunar science and exploration and engage the public in learning about the process of science discovery.

The Moon Zoo Science Team welcomes comments and feedback from the lunar science community on the project science goals defined in this abstract.

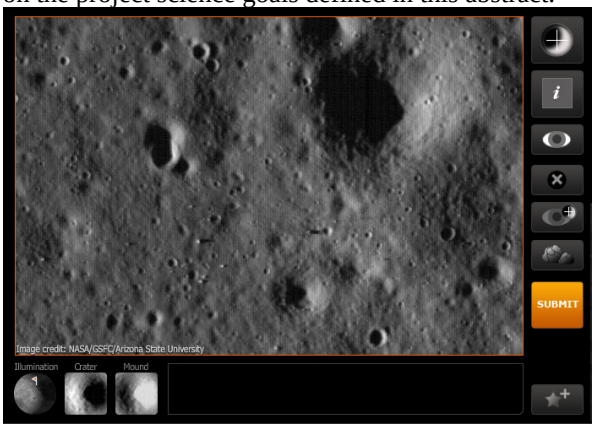

Figure 1. Beta-version Moon Zoo website interface for the crater dimension project. The GUI allows users to measure crater dimensions (Project 1a), identify craters with boulders (Project 1b) and spot any 'interesting' features (i.e. Project 4). Example lunar image courtesy of NASA/GSFC/Arizona State University.

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Acknowledgements: K. Joy and C. Lintott thank The Leverhulme Trust for financial support. *NASA Roses Grant NNX09AD34G.

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