THE MARS AUSTRALIAN REMOTE VIRTUAL EXPERIMENT LABORATORY (MARVEL): A MARSIS RESEARCH PLATFORM FOSTERING STEM EDUCATION EXCELLENCE.

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Introduction: The Mars Australian Remote Virtual Experiment Laboratory (MARVEL) project is a virtual laboratory for processing, computational analysis, and interpretation of publicly available digital data from NASA and ESA missions to Mars. To date the project involves researchers from 8 organizations: the University of South Australia (UniSA), Amazon (AWS), DiUS – Melbourne and Sydney, the Italian National Institute for Astrophysics (INAF), the Australian Centre for Astrobiology (ACA) at the University of New South Wales, Flinders University (Adelaide, Australia), University College London (UCL) Adelaide branch, Jacobs University, and volunteers from these institutions as well as other non-academic institutions and schools (the MARVEL team). Work on the system architecture for the project commenced in the first half of 2015, with deployment of the virtual laboratory planned in early 2016, and proof-of-concept testing for a period of 12-18 months. Testing will be conducted by two groups of users: (1) power users, comprising scientists, science education researchers, software engineers and programmers from all 8 organizations; (2) end-users, represented by selected planetary scientists, educators and school students.

The aims of the project are threefold: (1) to facilitate scientific collaboration among the researchers involved in the development of the laboratory, and in the process develop research tools; (2) to enable and encourage scientific collaboration with the broad planetary research community; (3) to engage educators and students in planetary research, facilitating distribution and exchange of data and modules for curriculum content in science, technology, engineering and mathematics (STEM) disciplines.

In this proof-of-concept implementation phase MARVEL is wholly supported by AWS infrastructure and scientific computing (co-author: White), DiUS data analytics, commercialization and marketing teams (co-author: Ngov), and by the scientists and education researchers in the academic and research institutions working on the core project to deliver the system architecture, the data, and the processing tools. Selected end-users during the proof-of-concept testing phase will be able to access the laboratory by invitation. In addition to collaborating on the design of the platform, the generation of the content and interface, and on the education and outreach protocols, the co-authors of this presentation are also concerned (at various levels) with the acquisition of resources (funding and staffing) and maintenance of the data sets, needed to guarantee the project long-term sustainability.

Here we outline the scope and scale of the MARVEL project, emphasizing particularly the education research aspect of the project.

MARVEL highlights: The virtual laboratory was conceived as a platform to facilitate collaborations among scientists (first author Caprarelli; co-authors: Orosei and Rossi), specifically in relation to the processing and geologic interpretation of the ground penetrating radar data from the Mars Express MARSIS experiment. The nucleus of the MARVEL work is therefore centered on the analysis of ground penetrating radar data sets (public distribution through ESA's, http://www.rssd.esa.int/index.php?project=PSA, in progress; Orosei), the programming tools needed for signal processing, and the georeferencing tools (PlanetServer; Rossi, http://planetserver.eu) required to generate intermediate level products useful for geological reconstruction. Higher level processing, leading to finished digital maps and radargrams, is designed to be shared with other scientists by way of a public interface, through which data requests are conducted upon subscription to the platform. A separate but closely linked section of the laboratory provides guided access for educators and students willing to use Mars publicly available data, including high-level processed MARSIS data, principally queried and visualized through a specifically designed MARVEL access tool to the JMARS (Java Mission-planning and Analysis for Remote Sensing, https://jmars.asu.edu) on-line GIS and to PlanetServer. Many existing public servers and data repositories grant access to finished products (maps, pictures) and Mars digital data for non-mission scientists, the public, teachers and students. The unique aspect of MARVEL is that the education and outreach platform section is designed by scientists, teachers, artists, software design engineers (all members of the MARVEL Team), and space education researchers (co-author: Oliver) to satisfy specific curricular requirements for students in primary and secondary schools in Australia. The goal of this collaborative effort is to build a virtual laboratory capable of drawing-in students, keep them engaged, and in the process achieve defined curricular targets while motivating the students with level-specific problems formulated by the MARVEL scientists and modified and tailored for the knowledge level of the students by the MARVEL team education experts. In the implementation design of MARVEL, the students become effectively the scientists' research assistants.

Science education concepts and MARVEL philosophy: Over the past 30 years there has been in Australia a steady decline in student participation in senior years high-school science, underlined by evidence that high school students consider science to be either irrelevant or not sufficiently creative to be interesting [1]. This has been attributed to the fact that science teaching at school is not at all related to actual scientific investigation and methods [2].

The *Pathways to Space* project pioneered under the auspices of the first ever awarded Australian Space Research Program Education Grant in 2010, was established as a consortium of universities, industry and public museums, which developed a Mars Yard concept addressed at K10 (15 to 16 years of age) students from public schools in the greater Sydney area. In the yard the students were able to work with engineers testing models of Mars rovers, and literally walk on a mock Martian surface. A selected group of students also engaged in the NASA Mars education team's Mars Student Imaging Project (MSIP), developing a research program to study the possibility of hydrothermal circulation caused by impact craters on Mars by examining and interpreting THEMIS data. After completing the project the students reported their findings and conclusions at the 2012 Australian Space Science Conference, and published a paper in the peer-reviewed conference proceedings [3]. Throughout this investigation the students had the possibility to interact on a continuative basis with Mars scientists in Australia and in Arizona, and with STEM education researchers (led by Oliver) who guided the program. The researchers were thus able to collect hard evidence demonstrating that direct engagement with scientists, working on actual research questions, motivates students to not only take an interest in science, but to go beyond the mere execution of instructions while developing genuine problem-solving skills [1;4].

The MARVEL virtual laboratory furthers and focuses this STEM education approach: it is a virtual platform primarily created by planetary scientists in collaboration with software engineers and computer programmers for the purpose of scientific collaboration and exchange of data and programming tools. Its open interface provides also a controlled entry to the laboratory, which can then become an ideal mixing environment for scientists, STEM education researchers and students. Scientists outline and focus real problems for which they need help from the student-force, which is engaged in the projects via tailored activities, while STEM education researches are able to gather evidence on the effectiveness of the virtual laboratory in raising the level of scientific interest in students. Participating schools gain useful curricular resources, with state of the art scientific content presented in pedagogically sound ways. Students will decide whether they want to participate in the scientific research beyond a basic level of engagement (necessary to fulfill curricular requirements). We anticipate that the highest levels of participation in scientific investigations will lead to students co-authoring publications, thus giving those students first-hand experience of the entire process of scientific investigation: from hypothesis formulation, to hypothesis testing and experiment design, to data collection and reporting, to interpretation and communication of the results.

Conclusions: The MARVEL project is being developed to achieve the dual objective of scientific research and STEM education. The proof-of-concept implementation stage is about half way through. Here we reported on the fundamentals of its STEM education aspect, which follow from evidence-based research conducted in Australia over the past few years, demonstrating the effectiveness of students' direct exposure to the work of scientists and to science investigation methods. The virtual laboratory will produce scientific research, STEM education research, and contribute to leading the way in Australia for structured science education in schools.

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