Introduction: The 2016 CanMars MSR Analogue Mission was a Mars Sample Return Analogue Mission carried out in partnership between the Canadian Space Agency and the Centre for Planetary Science and Exploration (CPSX) at the University of Western Ontario, as part of the NSERC CREATE project “Technologies and Techniques for Earth and Space Exploration” (create.uwo.ca) [1]. This mission, like its predecessor in 2015, provided an ideal setting to test the use of immersive virtual reality technology to aid scientists in conducting remote field operations. Implementing the use of virtual reality (VR) technology for the second year in a row also allowed the Geographic Information Systems (GIS) team to build on lessons learned last year [2], as well as take advantage of several key advancements in the technologies used.

Background:
Datasets. Prior to the start of the analogue mission, the Science Team was provided with a number of remote sensing datasets. For a full list of the datasets used during the 2016 CanMars Analogue Mission see [3]. Here the 5 m vertical resolution digital elevation model (DEM) along with the full colour 60 cm per pixel resolution QuickBird satellite image formed the basis of the 3D digital terrain models generated during the 2016 analogue mission.

VR Headsets. For the 2016 CanMars Analogue Mission several of the new Google Cardboard 2 VR headsets were made available to the Science and Planning teams for viewing immersive media. The Google Cardboard 2.0 works in concert with a directionally sensitive smart phone to create a platform to view data in a visually immersive manner [4]. The Google Cardboard acts as a frame to house 2 biconvex 45mm lenses and a smart phone. The screen of the phone projects an image or scene in a side-by-side stereographic format which is focused through the lenses to the user’s eyes allowing the user to focus on the displayed image as if it were in the distance. The accelerometer within the smart phone is used to track the phone’s orientation and constantly update the image or scene displayed as the user turns his or her head, creating the illusion of looking around a scene while standing at a fixed point within it. Similar devices have been used by NASA as part of the Onsight program to simulate the environment around active rovers on Mars. Augmented reality (AR) and VR headsets allow scientists to walk around the terrain, viewing the rover and landscape from multiple perspectives providing a key new tool to assist in navigational and scientific decision making [5].

Methods: For the 2016 CanMars Analogue Mission the GIS & Mapping team created two 3-Dimensional digital terrain models based on the 5m DEM provided.

ArcScene Model. Unlike the 2016 CanMars Analogue mission, the 2017 mission was given exact GPS coordinates for each of the rover’s waypoints and features of interest. The implementation of GPS coordinates into the analogue mission scenario also allowed the GIS and Mapping team to georeference each of the provided geospatial datasets to one another [3]. The exact rover waypoints, features of interest, and georeferenced remote sensing derived datasets were combined to form a geospatial database primarily accessed through ArcGIS. A 3-D model of the same terrain and data sets was also generated using the ArcScene program. The 5 meter DEM provided the base heights for the topographic model. The other datasets were overlain on this model to create 3-D surface maps, geologic maps, traversibility maps, line-of-sight communication maps, and to provide different points of view beyond the top-down satellite view of these datasets available in ArcMap.

Sketchfab Model. The online modeling program Sketchfab was used to create a 3-D terrain model that was hosted online and capable of supporting immersive VR functionality. This online terrain model was created via a series of steps. First the Digital Terrain Model provided prior to the start of the mission was rendered in the ENVI GIS program. Once rendered in 3D at maximum resolution, this DEM was exported and converted in to a Virtual Reality Modeling Language (VRML) format. The VRML file was then uploaded to the Sketchfab online modeling site. Once in Sketchfab the blank terrain of the VRML file was overlain with the QuickBird image of the landing site. Sketchfab is limited to an overlay of one texture or image, resulting in an online 3D Terrain model that could only be displayed with the satellite image, and none of the other datasets included in the ArcScene model. Once aligned properly the team had an easily navigable high-resolution model of the landing site (Fig 1). This 3D model could be shared by team mem-
bers via a URL and rendered on any computer, smartphone, or tablet, eliminating the need for specific GIS software to view a 3D model of the landing area. Advancements in the Sketchfab program allowed the 2016 GIS and Mapping team to fine tune the position and viewing angle of the model overall, as well as for the starting point of the camera when the terrain was viewed immersively. For VR viewing, the starting point of the camera was set to be approximately 2 m off the ground level, and located near the centre of the virtual field site facing the easily recognizable terrain features named Jotenheim.

Results:

ArcScene Model. The ArcScene terrain model provided additional perspective into the topography of the operational landing sight and surrounding region. Access to both exact coordinates and elevations of rover waypoints enabled the GIS and Mapping team to calculate both distances across the terrain and the height of features within the model. This allowed the science team to compare the sizes of the two largest hills in the rover’s operational area, Ragnorok and Jotenheim, as well as compare the elevation of individual sedimentary layers between observed outcrops. Observations from the elevation comparison enabled the GIS and Mapping team to confirm that the sedimentary layers in the landing site region were practically flat lying beds, with a calculated dip of 2º to the west. The 3-D ArcScene model was recognized as a useful tool for initial planning of rover traverses as well as deciding on the locations and orientations of images taken by the rover’s cameras [6].

Sketchfab Model. The improved immersive 3-D terrain model hosted through the Sketchfab online program enabled members of the Science and Planning teams to navigate a digital version of the field sight in a completely new way. By looking around the scene in VR a user can place a small cursor on a different location within the virtual landscape. By pushing the action button on the VR headset, the user would cause the camera to jump to a new location as indicated by the position of the cursor, while the camera remained the same elevation above the simulated terrain. This enabled a “look-to-walk” functionality that allowed users to navigate the full virtual field space as if they were walking across the terrain, albeit at a low resolution for both the vertical relief of the terrain as well as the satellite image stretched over the model.

Conclusions: Both the ArcScene and Sketchfab terrain models provided multiple perspectives of any spot within the operational field area. This provided the Science Team additional insight while planning future actions of the rover. The first-person view of the landing site through the use of the VR technology, provided team members with a sense of scale and direction that were not inherent to the other 2 and 3-D models of the site. This sense of scale held true for team members who visited the field site after the conclusion of mission operations, which had not been true for previous visits to analogue missions sites for missions conducted in previous years.

It is important to note that the DEM used was not able to render surface features with less than 5 m of vertical relief. Thus it can be concluded that the while the immersive VR setup used provided an accurate sense of scale for the largest features, but did not accurately portray the smallest topographic features and details within the operational field site.

Figure 1. 3-D terrain model rendered in the Sketchfab online model-rendering program.


Additional Information: The online immersive 3D terrain can be explored at the following link: https://sketchfab.com/models/8679c8c68d09485f89b7e c68fbe1cbe7

To navigate this model on a computer, use the “first person” viewing mode via the gear icon at the bottom right of the model window. To view this model immersively, access the link on a smartphone, select the VR headset icon at the bottom right, and place your device into a VR headset to view.

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