REVISITING APOLLO 17 STATION 6 BOULDERS WITH PHOTOGRAMMETRY, VIRTUAL REALITY AND STEREOSCOPY. S. Le Mouélic[1], B. Seignovert[1], G. Caravaca[1,2], H. H. Schmitt[3], N. Mangold[1]., P. Enguehard[1], [1]LPG, CNRS UMR6112, Univ. Nantes, France. [2]IRAP, UMR 5277 CNRS, UPS, CNES, Toulouse, France. [3]Dept of Engineering Physics, Univ. Wisconsin-Madison, P.O. Box 90730, Albuquerque, NM 87199, USA.

Introduction: During their third Extra-Vehicular Activity, Apollo 17 astronauts had the opportunity to photo-document with their Hasselblad cameras a collection of five large boulder fragments and regolith, lying at the base of a long trail descending from the North Massif [1] (Fig. 1). We recombined these original photographs using photogrammetry techniques to reproduce 3D digital models of the boulders [2]. These digital copies of the boulders can then be reinvestigated using either a web based platform (e.g., Sketchfab), or with a Virtual Reality headset on a dedicated SteamVR scene. Whereas the original images were not native stereo pairs, series of stereoscopic pairs can also easily be numerically recomputed from the 3D model in order to provide immersive views using a more conventional stereoscope system, for outreach purposes.

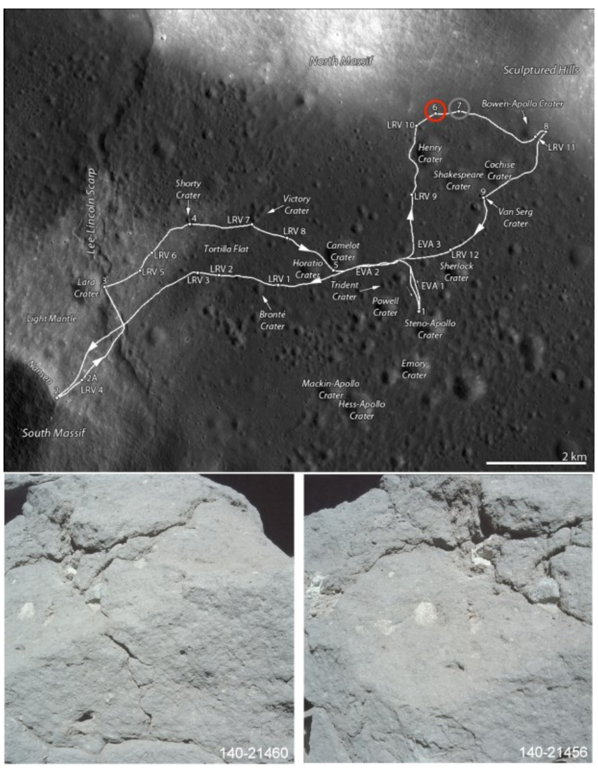

Figure 1*: Top: Apollo 17 traverse map and location of EVA3 station 6. Bottom : example of original images used as input for the 3D reconstruction (Apollo images 140-21456 and 140-21460)*

The Apollo data set: During the Apollo missions, astronauts documented the lunar surface, rocks and boulders using Hasselblad cameras equipped with 60-mm and 500-mm focal length lenses.

We focus here on boulders at station 6 of the Apollo 17 landing site, which have been thoroughly sampled by geologist-astronaut Harrison H. Schmitt and Gene Cernan. The Apollo image collection has been numerized and is now available on public websites, and can serve has input for photogrammetric studies [see 2].

Photogrammetry principle: The Structure-from-Motion photogrammetry principle relies on the identification of tie-points on a set of overlapping images taken from different points of views [e.g. 3]. When a sufficient number of overlapping images of a given scene is available, it is possible to compute the position of tie points in a 3D space, together with parameters linked to the camera used to take the pictures. Using a dense point cloud, a 3D mesh can then be reconstructed to provide the shape of the elements constituting the landscape. Individual images are then mosaicked and wraped over the mesh to provide a final numerical 3D model. Several commercial or open-source softwares can be used to perform all the processing steps. Here, we used a set of 82 Apollo images taken at station 6 during EVA 3 on several meter scales boulders (Fig. 1). These data appear to be suitable for a photogrammetric 3D reconstruction, as images have been acquired with enough overlap and from different points of views.

3D reconstruction of the station 6 boulders: Due to an incomplete coverage, the photogrammetric project was separated into three chunks. Fig. 2 shows the photogrammetric chunk corresponding to the northern most fragment, referred to as Boulder 1 (also informaly know as "Tracy's rock") [1, 4, 5].

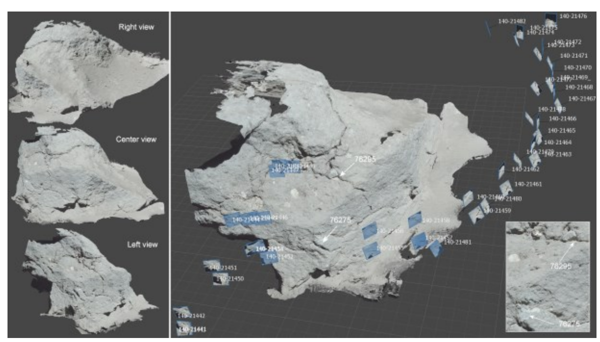

Figure 2*: Photogrammetric project showing the location of the 42 Apollo images surrounding the reconstructed textured 3D model of the first boulder at station 6. The inset shows a zoom of the 3D model, with arrows pointing to sampling locations.*

The position of the cameras has been automatically retrieved by correlation for each of the 42 frames (blue rectangles). A textured 3D model has been produced from this reconstruction. The inset in Fig. 2 shows a zoom illustrating the level of details that can be achieved in the 3D reconstruction, allowing for example to precisely visualize the sampling locations (often appearing with white-bluish tints). The scaling relys on a known reference such as the gnomon, or footprints, when available in the original images. Alternatively, the position of the cameras, attached at the chest of the astronauts, can be used as a second scaling constrain.

Rendering of the results: Several possibilities can be used to visualize, exchange or manipulate the 3D results, from the simpliest to more complicated ones. On the more traditional side, we can recreate anaglyphs seen with red-blue glasses Fig. 3 (left) or any stereoscopic pairs (Fig. 3 middle and right). Stereoscopic pairs can be wieved either by crossing the eyes, or with for example an inexpensive “OWL” viewer stereoscope [6], allowing to easily recreate three dimensionality for the viewer.

Web based platforms also provide a convenient solution to display single digital 3D models, with a rendering performed either on a conventional computer screen, in Augmented Reality with a smartphone/tablet, or even directly in Virtual Reality (VR) with a headset. Our 3D models of the station 6 lunar boulders can be freely visualized and manipulated in AR/VR at the URL https://sketchfab.com/LPG-3D.

To go one step further, publicly available game engines provide with the possibility to enrich the immersive experience by integrating the local 3D models with orbital imagery such as Lunar Reconnaissance Orbiter, recreating all the illuminating conditions in real time, and even allow the visit of a scene by several users simultaneously, interacting with each others. We have computed a basic scene allowing VR users to visit the station 6 boulders on the SteamVR community workshop plateform (Fig. 4).

Scientific interest of the Virtual Reality reconstruction: One of the main interests of the VR reconstruction is to give a real sense of scales, without the deformations induced by reprojections on a conventional computer screen.

The photogrammetric reconstruction integrated in VR also provides a way to visualize and manipulate a whole set of images, in order to interpret and extract their scientific content, and to possibly exchange directly between collegues or student as if they were on the same field trip.

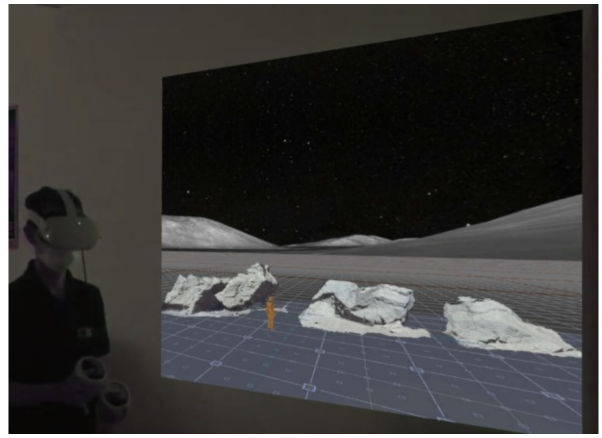

Figure 4*: Any user with a VR headset can revisit the station 6 boulders on a dedicated scene using the SteamVR platform (*https://steamcommunity.com/sharedfiles/filedetails/?id=2676700770*). The orange avatar represents the user in the scene at 1:1 scale. AR rendering can also be achieved from the web based Sketchfab platform.*

Conclusion and future work: We have reconstructed in 3D and integrated in VR several meter-scale boulders explored by Apollo 17 astronauts [2]. In the case of boulders at Station 6, the VR integration allows to visualize the morphology of the boulders, and also to precisely locate the lunar sampling areas in their original context. 3D scans of the samples themselves could be included in the VR scene in further works, to add an additional layer of contextual information.

References: [1] Schmitt, H. H., et al., Icarus, 298, 2-33, 2017. [2] Le Mouélic et al., Remote Sensing 12(11), 1900, 2020. (doi.org/10.3390/rs12111900). [3] Westoby M.J. et al., Geomorphology 179, 300-314, 2012. [4] Haase, et al., Earth Space Sci. 2019, 6, 59–95. [5] Wolfe et al., U.S. Geol. Surv. Prof. Pap. 1981, 1080, 225–280. [6] London Stereoscopic Company, London, United Kingdom

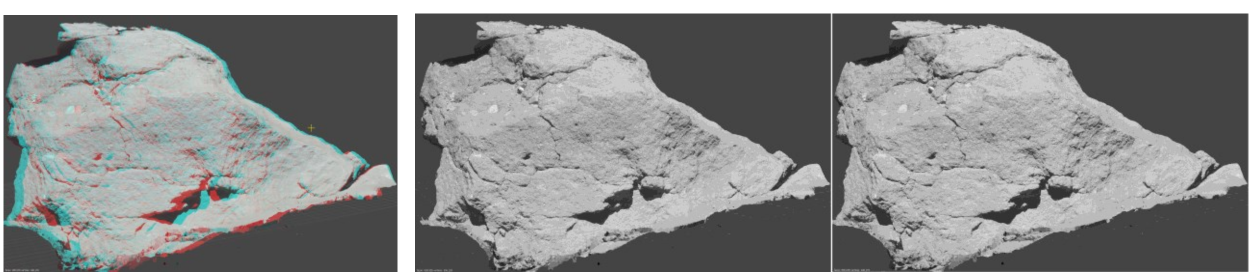

Figure 3*: Left: Boulder 1 in anaglyph mode. Middle and right : Stereoscopic pair recreated from the 3D photogrammetric reconstruction. This pair can be seen by eye crossing, or more conveniently using a stereoscope such as the “Owl” system*