GEOBUS *MISSION TO MARS!* A UK STEM EDUCATION AND OUTREACH RESOURCE. C. R. Cousins[1], J. Brooke[1], R. Robinson[1], and the St Andrews GeoBus team. [1]School of Earth and Environmental Sciences, University of St Andrews, St Andrews, Fife, UK, KY16 9AL. Email geobus@st-andrews.ac.uk.

Introduction: Space exploration is an excellent conduit for bringing science and technology education to schools. However, the fast-moving nature of scientific discovery during active missions means new findings and scientific knowledge are not incorporated into mainstream UK school education until years later. Moreover, space exploration incorporates aspects of all STEM (Science, Technology, Engineering, and Maths) subjects, providing a demonstration of the existence and importance of cross-disciplinary STEM applications.

Knowledge transfer into mainstream education must support teachers in delivering material that they might otherwise be less confident in or experienced with. The challenge is to bring space exploration directly into the classroom environment, in a manner that is not only inspirational, but constructive in helping pupils obtain their secondary school (high school) qualifications. We sought to create resources that will incorporate ongoing Mars exploration research and technological development into UK secondary school education. To achieve this, we developed an interactive workshop for the established GeoBus educational platform at the University of St Andrews.

Geobus. Established over 6 years ago, GeoBus is an educational organisation that delivers academic geoscience research to secondary schools across Scotland, through running hands-on workshops, field trips, and classroom-based lessons (see geobus.st-andrews.ac.uk for more information). GeoBus classes align learning outcomes from activities to the Curriculum for Excellence in Scotland, enriching the secondary education of pupils across the country, including visiting schools within the top 25% of the Scottish Index of Multiple Deprivation. To date, GeoBus has delivered this unique style of education to over 65,000 pupils in 250 individual schools across Scotland, in addition to contributing to many public engagement events across the UK. We created a series of educational workshops packaged together as a *Mission to Mars!* resource, suitable for delivery both in schools and at public outreach events.

The *Mission to Mars!* resource: *Mission to Mars!* has four components: (1) hands-on 50 minute classroom activities that operate individually, or in rotation (e.g. for a full-day event), (2) a 50 minute event for a large group, (3) a follow-on experiment to be completed by schools after the GeoBus school visit, and (4) online teaching resources including powerpoint slides, factsheets and handouts, 'geology in a minute' videos, and worksheets available for anyone to download and use. The online teaching resources especially enable schools to expand on elements of the workshops and activities themselves (e.g. for classroom workshops that prove particularly popular for a given school) and allow teachers to independently deliver material that fits with a range of STEM learning outcomes across all secondary year groups.

The *Mission to Mars!* resource is primarily based around the European Space Agency ExoMars rover mission, scheduled to launch in 2020 [1]. The objective is to teach pupils about how robotic platforms explore the surface of Mars, and also to raise awareness of the UK's growing involvement in space exploration and possible career paths within space. Recent findings from the NASA Mars Science Laboratory *Curiosity* rover are also incorporated, as well as older images from the Mars Exploration Rover missions. Standalone activities include:

Where to land? Students use 3D glasses to study anaglyphs of the martian surface, using both images taken from surface rovers and from orbit. Students identify and list the different landforms they can identify in the anaglyphs, and explain how they would form on Earth. They select and draw one particular landform they think would be the most interesting to send a mission to, and explain what they would expect to find there, and what hazards a rover would encounter. With this context, students can then create group posters for a rover mission of their own creation, thinking critically about the main requirements for their mission.

Figure 1. Jen from GeoBus explaining what an anaglyph is and how to study them.

How to land? Students are introduced to the Mars Science Laboratory *Curiosity* mission and the ExoMars mission, including the Trace Gas Orbiter, ExoMars 2020 rover, and Schiaparelli lander. They discuss the difficulties of landing on Mars, and how they might be mitigated. The students can then have a competition, either individually or in groups, to engineer a 'soft lander' out of cheap, common household objects to safely 'land' an egg onto the ground, with the winner being the team who can drop their egg from the greatest height without it breaking.

Mission Manoeuvring. Students identify similarities and differences between the GeoBus programmable rover 'Recon 6.0' with Martian rovers, such as ExoMars or Curiosity. They then devise a sequence of commands to program into the rover to plot a course across a martian 'terrain' mat laid out on the floor. This terrain has features to explore with the rover, such as dunes, rocks, river channels, and volcanoes, which can be supplemented with other objects or rocks. The students then use a different rover that is controlled in real-time to navigate to find and study rocks using only the rover cameras as their view-point. For each feature the students discover using their rovers, they take an image of the feature, log a description in their geology notebook, and make possible interpretations.

Figure 2. Programming a course for the rover to follow in order to investigate rocks and avoid hazards.

Rocks and minerals from Mars. Students study and describe sandstone hand specimens, hypothesising on how they formed and what textures they observe. They then look at basalt thin sections under a light microscope, making a labelled drawing of what they see, and discuss how the two rocks differ. Lastly, students discuss the role of water in producing certain minerals, and how these are used to identify places where life might have once survived. Their last task is to grow halite and magnesium sulfate crystals under a light microscope, observing how salts precipitate out of solution, and how different chemistries produce different types of mineral.

Spectral technology. Students learn about the electromagnetic spectrum, and how different wavelengths of light can be used to look at different features on Mars. They then take part in demonstrations using a thermal infrared camera, and in groups use educational visible wavelength spectrometers (Ocean Optics Education Kit) to analyse different soils and other materials, as well as investigate materials that fluoresce under UV illumination.

Scientific literacy. Students are given a number of information sources, some reputable and some not. They have to decide which ones are trustworthy, and then further identify which ones support the possibility of life on Mars. They then follow this up by dividing into groups, each of which is given a news article that details a real scientific discovery. The groups then create their own article of 'fake news', and the other groups have to establish which article is real, and which is fake, and why.

Looking forward - Humans on Mars? Using clips from the film The Martian, students identify and discuss factors that make it difficult for humans to explore Mars. This is followed by a more in-depth discussion about how to feed people on Mars. Students set-up their own experiments to be conducted over several weeks. They collect some 'Earth' soil, and compare this with 'Martian' Mars-analogue soil provided by GeoBus by measuring pH and nutrient content in both. Following a discussion about what plants need to grow, the students set up their experiments by planting cress and lettuce seeds in the soils and changing parameters such as pH, temperature, light etc.

Overall, the compartmentalised nature of these resources is intended to make them adaptable to events taking place outside of the school environment, such as large public engagement events. Likewise, the hands-on experiments are designed to be adaptable to different academic capabilities and specific learning requirements. Finally, through delivery with GeoBus, it is possible to combine experiments using cheap or pre-existing items, with those that use specialized equipment not usually available to teachers (petrographic microscopes, spectrometers, IR cameras etc).

References: [1] Vago J.L et al. (2017). *Astrobiology*, 17, 471-510.

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