OUT-OF-SCHOOL TIME ENGINEERING AND PLANETARY SCIENCE UNITS DEVELOPED BY THE PLANETS PROJECT. R.B. Anderson[1], M.E. Rumpf[1], J. Clark[2], R.G. Vaughan[1], L.M. Pigue[2], L. Rubino-Hare[3], S. Ryan[3], J.M. Powers[2], C. San Antonio-Tunis[3], N. Bloom[2], C.Haden[4] [1]USGS Astrogeology Science Center, Flagstaff, AZ (rbanderson@usgs.gov), [2]Northern Arizona University, Flagstaff, AZ, [3]Museum of Science, Boston, MA [4]Magnolia Consulting, LLC.

Introduction: PLANETS (Planetary Learning that Advances the Nexus of Engineering, Technology, and Science) is a NASA-funded project (#NNX16AC53A) aimed at developing out-of-school time (OST) content to engage middle- and elementary-school students, particularly those underrepresented in science, technology, engineering, and mathematics (STEM), in the excitement of planetary exploration. The PLANETS project involves a collaboration between subject matter experts from USGS Astrogeology, education and professional development experts from the NAU Center for Science Teaching and Learning (CSTL), and the Engineering is Elementary program at the Museum of Science, Boston.

PLANETS has developed three OST units (Figure 1), focusing on remote sensing, water in extreme environments, and the hazards of space exploration. For each unit, we developed separate but complementary engineering and science content, as well as educator resources such as videos to help introduce key concepts and ensure that educators are prepared to teach the units. Units are pilot tested and we conducted research on how educators implement the units in various contexts to support youth STEM learning, and how participating in PLANETS activities influences youth's attitudes toward engineering.

Remote Sensing: Remote sensing plays a fundamental role in all space exploration, and has many real-world applications, so it was the focus of the first unit developed. This unit is targeted toward grades 6-8 and consists of the "Worlds Apart: Engineering Remote Sensing Devices" engineering activities, and the "Remote Sensing of Mars" science extension unit.

In Worlds Apart, students learn how to use mirrors, filters, and LiDAR to design a remote sensing device to study a model planetary surface. In the Remote Sensing of Mars activities, students are introduced to data from actual NASA instruments (e.g. HiRISE, CRISM, MOLA, CTX) and are tasked with using the data to choose a safe and interesting landing site on Mars.

Water in Extreme Environments: Water is required for life as we know it, and therefore has been a key focus of much of NASA's exploration of the Solar System. At the same time, access to clean water is a critical challenge, not just for crewed missions to other planets, but for humans here on Earth. This unit likewise targets middle school (grades 6-8) youth. The engineering activities for this unit, called "Testing the Waters: Engineering a Water Reuse Process" teaches youth about water quality and filtration and asks them to engineer a process to re-use gray water in an extreme environment, whether that is a base on Mars, a space station, or an arid environment on Earth.

"Water in the Solar System" is the accompanying science content for this unit, and focuses on the distribution and physical state of water in the Solar System. A set of playing cards (Figure 2) illustrate the different water reservoirs on bodies throughout the Solar System, and students group the cards based on different criteria to achieve the learning goals and challenge the misconception that Earth is the body in the Solar System with

Figure 1: Cover art for the finished engineering and science content. Additional information, educator resources, and the units themselves are available at https://planets-stem.org/.

the most water. Several additional games can be played with the cards, providing the opportunity for additional learning either in the classroom or at home.

Space Hazards: The final unit, aimed at elementary school children (grades 3-5), focuses on the similarities and differences between hazards in space and on Earth and how engineering can help to mitigate those hazards. The engineering unit is called "In Good Hands: Engineering Space Gloves" and engages children to design space gloves that protect astronauts from hazards such as extreme temperatures, crushing hazards, and dust contamination while also remaining dexterous enough for astronauts to do their work.

The accompanying science content for Space Hazards is currently in development and involves a card game that introduces children to hazards and their mitigation strategies, first on Earth, then in different space environments (space station, Moon, Mars, asteroids). The science unit culminates with children planning their own mission to a destination in the Solar System and determining how best to mitigate the hazards that such a mission would face.

Results: The PLANETS project is committed to rigorously assessing the extent to which we are meeting our goals and NASA's top-level metrics for the Cooperative Agreement. To that end, we have collected a significant amount of information on the impact and efficacy of our products. To date, 2,235 adult participants and 2,938 youth participants have been directly involved in PLANETS project activities. A conservatively estimated 1,956 educators and 29,340 youth have been indirectly involved through curriculum downloads, covering all 50 states, the District of Columbia, and Puerto Rico. Analysis of survey data from a study of four OST sites that implemented PLANETS curricula with 52 middle-school-aged youth showed a statistically significant increase on youth's engineering attitudes on five scales: *enjoyment, value to me, school, value to society, aspirations* ($p<.001$). Observations of youth engaging in these activities suggest specific engineering practices that play a role in development of interest and affiliation include: *negotiating design decisions collaboratively, persisting through failure, and celebrating success*. In end-of-lesson focus groups some youth expressed an interest in engineering careers and confidence in their abilities to engineer and understanding of what engineers do.

Future Work: PLANETS is finalizing the science content for the Space Hazards unit, which will be sent out for pilot testing early in 2020. Field studies of the Remote Sensing and Water in Extreme Environments units is ongoing, with field testing of the Space Hazards unit planned for Fall 2020. The professional development products are beginning formal dissemination through the PLANETS website. External evaluators are currently analyzing data from a Fall 2019 field test of the Remote Sensing unit. The study sought to understand how educators used the materials, their perceptions of the materials, and how using them affected their teaching and subject knowledge. The study also sought to understand how the materials influenced student attitudes. The field test involved 11 OST educators and more than 300 youth at seven sites across the U.S. Data collection included an educator implementation survey, an educator knowledge and skills survey, educator interviews, and an engineering attitude survey for youth.

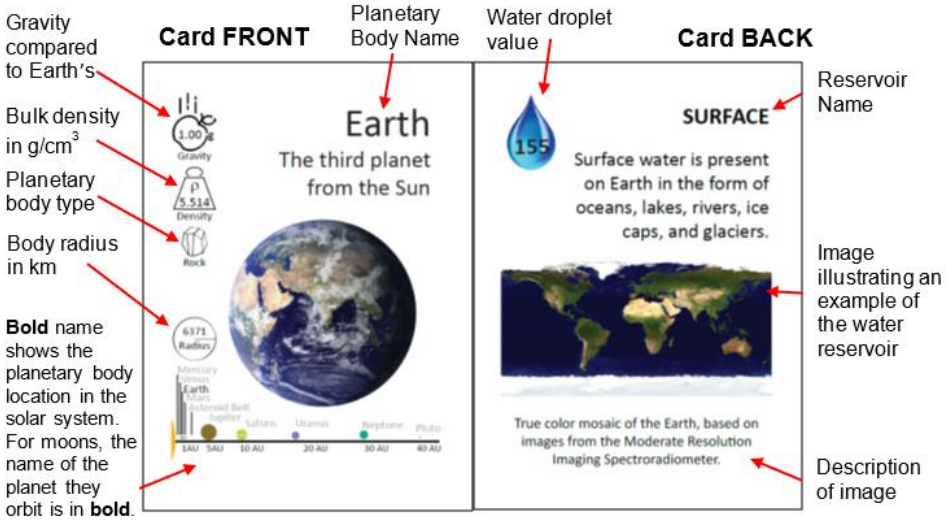

Figure 2: Example of one of the cards from the Water in the Solar System science unit. One side of each card contains basic information about the planetary body. The other side provides specific information about one type of water reservoir on that body. The number in the water droplet is a normalized representation of how much water is present in that reservoir, based on current scientific knowledge.