Visualizing Space Science: Touching to see and understand. C.J. Runyon[1], D. Hurd[2], C. Hall[1], M.Williams[1], K. Quinn[2], J. Matelock[3] [1]College of Charleston, Charleston, SC, runyonc@cofc.edu; [2]Edinboro University, Edinboro, PA, dhurd@edinboro.edu; [3]retired from Edinboro University.

Introduction: NASA's many successful space missions and discoveries have resulted in the acquisition of thousands of images, movie clips and a variety of data in a range of scales. These resources have helped most of us to visualize, interpret and map distant planetary surfaces, leading to extraordinary discoveries. But, what about your colleague, friend or family member who is visually impaired or blind? How might these discoveries and observations be as powerful for them as it is for you? We ask questions like this all of the time so that people with disabilities can have the same experiences as people without, whether it is understanding what an asteroid or small body is, experiencing a lunar or solar eclipse, or using spectroscopy to determine the composition of a planet's surface.

For the last two decades we have been working with students, colleagues, the National Aeronautics and Space Administration (NASA), the National Federation of the Blind (NFB), teachers and parents to make earth and space science accessible for all. We have held workshops for people from across the country who are, or work with persons who are, blind/visually impaired (i.e., students, parents, family members and teachers). With support from NASA Headquarters and the former NASA Lunar Science Institute (NSLI), three tactile books (*A Tactile Guide to the Solar System, Getting a Feel for Lunar Craters and Mars Science Laboratory [1-3]*) were distributed widely to schools for the blind, state libraries and many public and private schools and museums, all of which passed NASA's rigorous peer review and testing in the Blind/Visually impaired community. Another NASA-funded publication, *Space Science IS for Everyone: Lessons from the Field [4]*, summarizes seven years of working closely with the exceptional needs community to identify, implement, test and modify strategies, methodologies, activities, graphics and models related to Earth and Space Science. This community includes NASA scientists, engineers, educators, parents and students from across the nation.

We are currently funded by two grants from NASA Solar System Exploration Virtual Institute (SSERVI) involving two multi-national science teams (i.e., SEEED through Brown University and CLASS through the University of Central Florida) and lead their education / public outreach effort. The majority of this education / outreach effort includes developing an arts-infused STEM curricula and set of resources that inspires and engages students in the multidisciplinary field of STEAM, including those with disabilities. For the last two years, we have been designing and testing new formal and informal activities related to the formation, evolution and exploration of asteroids, meteorites, the Moon, Phobos and Deimos. Very few accessible resources related to these topics currently exist for use with students and audiences with disabilities.

Why the emphasis on Blind / Visually impaired? Nearly one-fifth (19.3%) of the U.S. population aged 5 years or older, or just under 50 million people, has some form of disability [5,6]. There are currently 21 million adults in the United States with a sensory disability involving sight, 127,000 in South Carolina alone [6,7].

Since the passage of the Individuals with Disabilities Education Act (IDEA) in 1975 (and reauthorization in 2004, [8]), there has been a profound shift in the responsibility for educating students with disabilities. Prior to 1978, 80% of students with disabilities in the K-12 arena were in institutions and received little schooling; by 2011, approximately 95% of these students were served at least some portion of the day in the general classroom. 61.1% of these students spent at least 80% of their academic day in an inclusive (i.e., non special education) classroom [9]. Very few of these classrooms, or schools, have adequate resources to accommodate these students; although IDEA 2004 states that "…educators and parents have the necessary tools to improve educational results for children with disabilities." [8] In the higher education community, inclusive learning environments persist, integrating students with disabilities into mainstream classrooms. Here still, inadequate physical resources (i.e., tactile models and graphics) are available to fully support these students. For example, while many colleges have an Office for Students Needing Access Parity, or SNAP Office, budget and staff constraints often limit their assistance to issues related to learning disabilities.

College and university faculty have very different obligations than those in the K-12 community. Most higher education institutions have only the obligation of making "reasonable accommodations," ensuring that their programs are accessible by students with disabilities and that the students are provided the necessary academic services and adjustments. It is the student's responsibility to identify her/himself, as having a disability, with the appropriate campus services and faculty members. These requirements involve substantial adaptations on the part of classroom teachers and faculty, who likely have little training or experience in working with students with disabilities, let alone creating resources.

On average, students with disabilities represent about 11% of the total population of undergraduates. Graduate students with disabilities comprise about 8% of the total population of graduate students in the science and engineering disciplines [5,11]. In addition, there are 309 students with disabilities pursuing doctorate degrees in science and engineering, representing about 1.2% of the total student population; 142 of those are in the social sciences rather than the "hard" sciences [11]. Many of these students do not pursue degrees in science, technology, engineering or math (STEM) fields because of the hands-on /fieldwork component, a key component of many of the science disciplines [12]. For those students who are Blind/Visually impaired, this is compounded by their inability to 'see' the landscape and be able to actively interpret their surroundings in real-time, whether it is in an outdoor geologic setting or an indoor laboratory setting.

The participation of persons with disabilities as STEM professionals is highly underrepresented: STEM professionals with disabilities make up a mere 7% of all employed professional scientists and engineers [11]. By increasing access to the STEM fields for college students with disabilities and by improving the quality of teaching of these disciplines, it is likely that more students with disabilities will consider pursuing STEM careers in the future. This includes increasing the availability of accessible resources for these students, particularly for those students who are Blind/Visually Impaired.

Tactile Resources in Development

Three tactile books and associated educator resources currently in production are:

1) Understanding small bodies in the solar system is an introduction to the meteorites, asteroids and the smaller moons in our solar system and our current understanding of their nature and composition. The emphasis for this tactile guide will be the use of spectroscopy to distinguish the similarities and differences of the various planetary bodies. Tactile graphics will illustrate the different sizes and textures of these small bodies.

2) Touch the Spectrum is an introduction to the electro-magnetic spectrum and its use and importance for space exploration. Examples include rock and mineral identification and planetary surface mapping, such as produced by the recent Moon Mineralogy Mapper (M3) mission.[9, 11,12,13] Tactile graphics include outlines of the full spectrum (UV – IR) and individual rock and mineral examples (e.g., olivine, pyroxene, anorthosite) from small bodies in the solar system.

3) Getting a Feel for Eclipses will take advantage of the fact that the path of the August, 2017 total solar eclipse will travel directly across the continental US, from Oregon to Charleston, SC. We have created a tactile guide to eclipses (Fig. 1). Tactile graphics will provide an illustration of the interaction and alignment of the Sun with the Moon and Earth. Associated activities will help to explain the nature of eclipses.

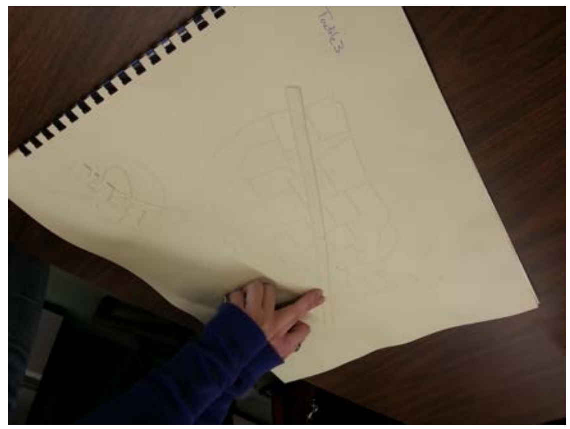

Fig. 1: Draft tactile graphic of upcoming total solar eclipse.

References: [1] Runyon C.J. and Hall, C.R. editors (2008) *Space science is for everyone: Lessons from the field*. NASA Headquarters. [2] Runyon, C.J. and D. Hurd (2008) *A tactile guide to the solar system*. NASA Publication. [3] Runyon C.J., Shipp S., Shupla C. Tuthill G., Halau K. (2008) *NLSI Lunar Science Conference #2067*. [4] Runyon C.J. (2006) *Proc.* Indo-US Science & Technology Forum, New Delhi, India, p. 187-195.[5] U.S. Census Bureau (2012) http://factfinder.census.gov. [6] National Federation of the Blind (NFB) (2015) http://nfb.org/blindness-statistics. [7] CDC, 2014, National Health Interview Survey (NHIS). [8] Individuals with Disabilities Education Act (IDEA) in 1975 (and 1997 and 2004). [9] National Center for Education Statistics. (2003). [10] American Youth Policy Forum & Center on Education Policy. (2002) http://www.aypf.org/publications/ special_edu.pdf. [11] NSF (2011) Report: NSF 04-317 http://www.nsf.gov/ statistics/wmpd/disability.htm. [12] Hall, T., M. Healey, M. Harrison (2004) *J.Geog in H. Ed.*, July 2004, vol. 28, # 2, 255-280. [13] Pieters C.M. and the M3 Science Team (2009) *Science Express*, 24.09.2009, 1178658.