GENERATING A 3D SHAPE MODEL OF 2014 MU_{69} FOR SCIENTIFIC VISUALIZATION AND PUBLIC OUTREACH. M. J. Kinczyk[1], K. Runyon[2], S. J. Robbins[3], J. T. Keane[4], W. M. Grundy[5], H. B. Throop[3], C. J. Bierson[6], C. B. Beddingfield[7,8], R. A. Beyer[7,8], O. L. White[7,8], J. M. Moore[8], P. Schenk[9], T. R. Lauer[10], W. B. McKinnon[11], A. Verbiscer[3], J. Parker[3], C. B. Olkin[3], H. A. Weaver[2], J. R. Spencer[3], S. A. Stern[3], and the New Horizons Geology, Geophysics, and Imaging Team. [1]Planetary Research Group, Dept. of Marine, Earth, & Atmospheric Sciences, NC State University, Raleigh, NC (mallory.kinczyk@ncsu.edu), [2]The Johns Hopkins University Applied Physics Laboratory, Laurel, MD, [3]Southwest Research Institute, Boulder, CO, [4]Division of Geological & Planetary Sciences, California Institute of Technology, Pasadena, CA, [5]Lowell Observatory, Flagstaff, AZ, [6]Dept. Earth & Planetary Sciences, University of California Santa Cruz, Santa Cruz, CA, [7]Carl Sagan Center at the SETI Institute, [8]NASA Ames Research Center, Moffett Field, CA, [9]Lunar and Planetary Institute, Houston, TX, [10]National Optical Astronomy Observatory, Tucson, AZ, [11]Washington University in St. Louis, St. Louis, MO.

Introduction: Visualizing and projecting data obtained from small body missions has historically been rife with challenges. The traditional ellipsoid-based projection of geographical data, while suitable for near spherical bodies, is incompatible with irregularly shaped small bodies. The Small Body Mapping Tool (SBMT) [1] was developed to address the problem of projecting various data types onto a previously determined shape model of the body. However, with a flyby mission such as New Horizons, a detailed shape model for MU_{69} (**Figure 1**) will cover approximately half the surface and will not be developed until higher resolution and higher phase images are downlinked from the spacecraft. Therefore, the ability to quickly generate a shape model for preliminary analysis and interpretation increases the scientific output of the mission.

Clay Model: The New Horizons Geology, Geophysics, and Imaging Team determined that a handcrafted model would both help each of the science teams in visualization and interpretation of data, and be an effective tool for public interaction during flyby press conferences. Though it was possible to generate a digital 3D model to be printed, the 3D printing process is time consuming. Spherical objects can be printed using two primary methods: (a) the object is printed on a scaffolding material that is then removed to reveal the final shape or, (b) it can be constructed as separate hemispheres that are then adhered together to form the final shape. The complexity of the 3-D printing process alone is a limitation in quickly constructing and interpreting surface features of small bodies.

The clay model (**Figure 2**) was constructed using a foam core and an airdry clay exterior. Two spheres were constructed and then modified to primarily replicate the limb topography in the Long Range Reconnaissance Imager (LORRI) observation CA04 [2]. Due to the low phase angle of the first few sub-kilometer pixel scale images received on January 1st (~11-13°), the ability of team scientists to accurately interpret topographic features was limited. While some areas were interpreted as topographic highs or lows for the sake of a preliminary shape model, digitizing will allow for manipulation of the shape model as a more sophisticated interpretation of surface geology is developed.

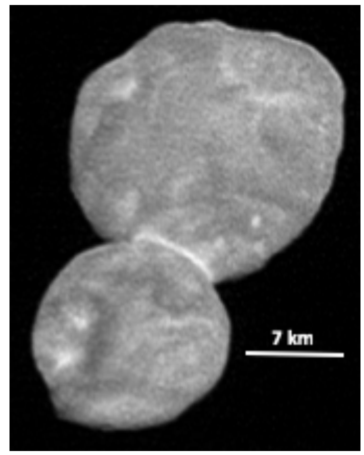

Figure 1. Deconvolved rendering of LORRI observation CA04 (~140m/px).

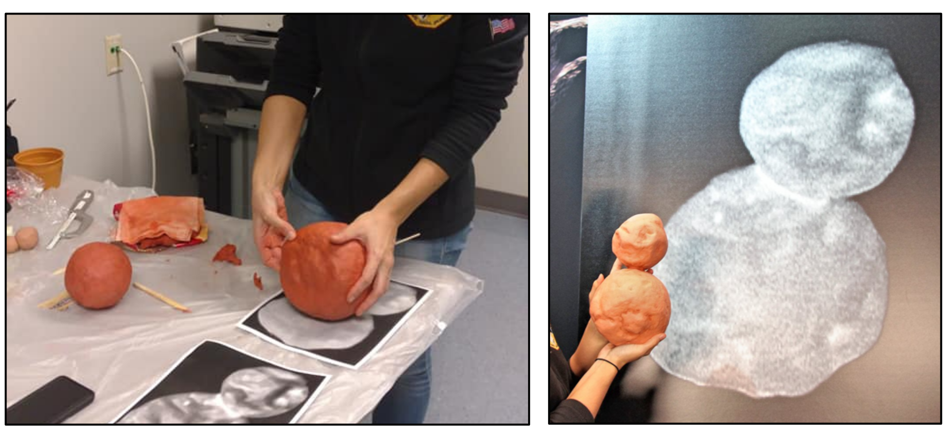

Figure 2. (a) Constructing the clay model (b) Model held next to flyby LORRI image at press conference. The clay model was used at several press conferences during the flyby week to enhance the discussion of critical findings. Credit for right image: Ken Kremer at spaceupclose.com

Digitizing: We used the Artec3D Space Spider professional 3D scanner to digitize the clay model interpretation of MU_{69} (**Figure 3**). The scanner is able to obtain a 3D resolution of up to 0.1 mm and a pointing accuracy of up to 0.05 mm. It uses a blue LED to acquire pointing data at 1 million points per second. The default processing steps in the accompanying Artec software cleaned most artifacts and rendered the model “water tight” such that there were no holes in the 3D model. This version of the model was resampled to remove artifacts from the digitizing process and exported to formats suitable for use in other 3D rendering programs and printers (e.g., Blender, MATLAB, uPrint, etc.).

Scientific Utility: During approach, an early shape model was used to (a) illustrate the nature of the unusual lightcurve observed by the spacecraft [3], (b) illustrate encounter geometry and to produce animations of the encounter for science and outreach purposes [4], and (c) to assess illumination and observation circumstances of the various observations. Prior to their being transmitted back to Earth, the initial shape model and approximate orientation already indicated that the highest resolution LORRI images could be expected to provide additional views of the "neck" region between the two lobes of MU_{69} that would be of considerable value for geophysical investigations regarding the aftermath of the merger event [5]. The model was also used by the navigation team to help with refinement of the post-flyby trajectory needed to determine exact observation geometry. The digitized model can be easily converted into a Digital Shape Kernel (DSK) in the JPL-NAIF SPICE system. When coupled with a pole position and rotation rate, the position and orientation of the body can be easily viewed by tools using SPICE, such as the GeoViz tool [6]. This allows for direct comparison between spacecraft data and simulated images, to visualize the flyby geometry and help interpret the data [7].

In general, the availability of shape models enhances interpretation of surface geology such as topography and down-slope movement of materials, as well as internal characteristics such as internal stresses. Early progress can be made even with highly approximate models. The final digitally rendered model (**Figure 4**) was distributed to the various science teams for use. The establishment of a defined coordinate system that will allow systematic mapping of the surface (such as in SBMT) is still in progress [8]. However, additional downlinked data may inform this decision as well as enhance our understanding of the shape.

Acknowledgments: New Horizons team members acknowledge funding from NASA’s New Horizons project. Special thanks to Drew Knuth with JHUAPL IceLAND for providing access to digitizing and 3D printing hardware during the flyby.

References: [1] Ernst, C. M. (2018) *LPS, 49,* Abstract #1043, [2] Bierson, C., et al. (2019) *LPS, 50,* this conference [3]Zangari, A., et al. (2019) *LPS, 50,* this conference, [4] Robbins, S. J., et al. (2019) *LPS, 50,* this conference, [5] Moore, J. M., et al. (2019) *LPS, 50,* this conference, [6] Throop, H. B., et al. (2009) *DPS, 41,* id.68.20, [7] Porter, S. B., et al. (2019) *LPS, 50,* this conference, [8] Beyer, R. A., et al. (2019) *LPS, 50,* this conference.

Figure 3. Digitizing the clay model using the Artec 3D Space Spider scanner. Due to the large size of the model, digitizing the whole irregularly-shaped object proved challenging. Image credit: NASA/JHUAPL/SwRI/Henry Throop

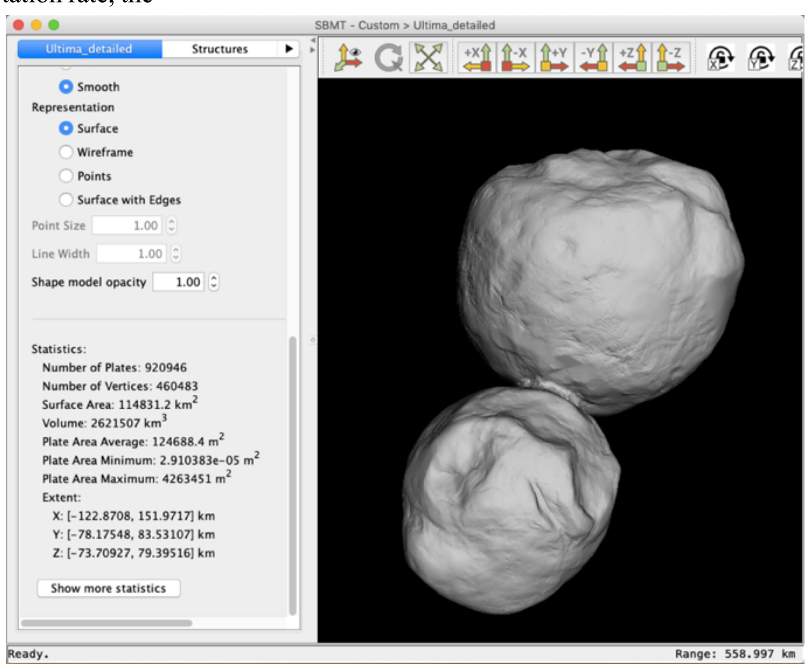

Figure 4. Digitized clay model displayed in Small Body Mapping Tool [1].