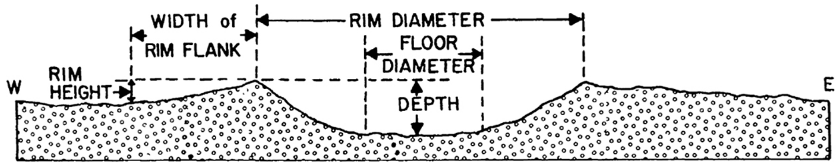

Figure 1. Major geometric properties of craters calculated by *Pike* [1976] for craters on the Moon [from *Pike*, 1976].

properties of complex craters and larger basins with complex interior topography have been the most difficult to quantify.

[6] Global characterization of crater geometries has been facilitated with more recently acquired global laser ranging data and derived gridded DEMs. In 1994, the Clementine lidar instrument provided topographic data along individual tracks separated by ~60 km at the equator and less elsewhere, with a north-south shot spacing along individual tracks of 20 km assuming a 100% pulse detection rate [*Smith et al.*, 1997]. Unfortunately, due to the lack of optimization of the lidar's receiver function during its ranging sequence, the instrument had many missed detections and false returns, detecting only 19% of returned pulses, with about 36% of these attributed to noise [*Zuber et al.*, 1994; *Smith et al.*, 1997; *Williams and Zuber*, 1998]. As a result, along-track shot spacing was more typically of the order of 100 km during a single orbital pass; smaller shot spacings as little as 4 km were achieved as the number of orbital passes increased over the course of the mission. While orbital shots were gridded into a 0.25° by 0.25° (~8 km by 8 km) DEM for latitudes between 79°S to 82°N, much interpolation between the large track spacing was necessary, resulting in high uncertainty in topography within these regions [*Smith et al.*, 1997]. For this reason, more reliable geometric characterization of craters and basins using Clementine lidar has used individual tracks [*Williams and Zuber*, 1998].

[7] With the current high spatial density of laser shots from the LOLA instrument—nearly 4.9 billion as of this writing—derived global DEMs of the lunar surface are substantially improved in resolution and reliability. There are now global LOLA DEMs of the lunar surface at a remarkable 1024 pixels per degree (ppd) (~30 m/pixel) resolution. While gaps in spatial coverage of laser tracks still exist, leading to necessary interpolation steps when producing LOLA DEMs, these gaps are orders of magnitude smaller than the ~60 km gaps of Clementine lidar tracks and are being filled systematically. The accuracy of individual radial measurements from LOLA is 1–2 m with respect to the center of mass of the Moon; however, the lunar potential is uncertain by as much as 20 m on the lunar farside. As a result of these uncertainties, it is customary for DEMs to use a spherical datum (IAU2006), where slopes are measured with respect to a planetocentric radial vector, not the local vertical. Errors in slope introduced by this assumption arise mainly from the equator-to-pole flattening, but may locally be as large as 0.14 degrees at the rims of mare basins.

3. Previous Methods of Topographic Measurements

[8] Manual topographic measurements of hundreds of craters is a tedious process, increasing in time and complexity with increasing crater size. *Pike* [1976] laboriously measured a number of geometric properties for hundreds of fresh craters on the Moon using Lunar Orbiter (LO) images and Lunar Topographic Orthomaps (LTOs). Five main properties were identified that were viewed as accurately characterizing the overall surface geometry of lunar craters (Figure 1): rim-crest diameter, width and height of the exterior rim flank, diameter of the flat inner floor, and depth (Figure 1). From these measured properties, several other geometries were calculated, including slope of the exterior rim flank, width and slope of the interior wall between the rim crest and crater floor, and depth of the crater below the pre-crater datum. For consistency with this widely cited study on crater geometries, we use mostly the same nomenclature and include similar measurements herein (see section 4 and Figure 2). For details on how these early crater measurements were made, the reader is referred to the description by *Pike* [1976].

[9] A major difficulty in calculating geometric properties of large craters has been accounting for their substantial azimuthal variation in topography, which appears to increase in complexity with increasing crater size [*Pike*, 1974, 1976, 1977; *Settle and Head*, 1977]. Small, fresh craters formed into a smooth homogeneous target are more likely to have the smallest azimuthally varying topography than more degraded or larger craters and basins formed by impacting into the same target. A pre-impact surface that is not-flat and featureless but sloping or is already heavily cratered can have large effects on the final topography of an impact structure. Other sources of topographic variation include heterogeneous target layering, varying impact conditions (impactor composition, impact angle, etc.) [*Melosh*, 1989; *Schultz*, 1992a], and post-impact processes such as younger impacts, volcanism or tectonism [*Head*, 1975]. Determining the relative roles of these processes in modifying the final crater's topography has been a major goal of previous and current analyses.

[10] To account for these topographic variations, *Pike* [1976] averaged multiple elevation points to obtain a single statistic. For example, a single value for the rim-crest elevation was determined by first visually outlining the crater's rim crest, then sampling multiple elevation points along this outline, using more data points for the largest crater diameters. The floor elevation was also obtained from multiple spot elevations; the depth of the crater could then be calculated by subtracting this average floor elevation from the average rim-crest elevation. While providing the most accurate crater measurements at the time, this technique was highly limited by the number and quality of the LTOs, with far fewer topographic measurements available from shadow measurements of LO images. It is also unclear how many points were used for these calculations and what criteria were chosen for identifying the locations of the rim-crest and floor spot elevations.