Introduction and Background: Crater population data are often used for the purpose of estimating the age of a planetary surface. The process of estimating a surface age from craters rests on the concept that the more craters a surface has, the older it is. The relative ages can be converted to model absolute ages by a model crater population function; see [1].

The researcher must then use a model crater PF to extrapolate the density of craters with diameters ($D$) greater than 1 km for a given age ($N(1)$). This is scaled via a published chronology function ("CHF") and the production function are minimized. The population data are often used for the purpose of estimating the relative ages can be converted to model absolute ages by a model crater population function; see [1].

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The PF is scaled via a published chronology function (e.g., 1, 2) that describes the crater density of all craters $D \geq 1$ km for a given age ($N(1)$); chronologies are only defined for what is termed "N(1)," the density of craters with diameters ($D$) $\geq$ 1 km. An alternative method to estimate ages is to use the number-density of all craters larger than or equal to a certain diameter $D$ in km ("N(D)") instead of fitting a range of diameters, and using the PF to scale to $N(1)$ (e.g., measure the density of craters on a surface $D \geq 10$ km, determine the ratio of $N(10)$ to $N(1)$ for the PF being used, scale to $N(1)$, then determine the age of that $N(1)$ from the chronology function).

Both these techniques for age estimation rely on and require a PF to relate crater densities to the diameter range. Other techniques typically rely on residual minimization, calculating the difference between each SFD datum and the production function value for a particular scaling factor at that diameter. The scaling factor is adjusted until the differences between the data and the production function are minimized. The popular CraterStats and CraterStats2 freeware [7] use IDL software's built-in "CURVEFIT" routine, which uses a gradient-expansion algorithm to compute a non-linear least-squares fit to the PF.

Potential Solutions: In mathematics and statistics, there are numerous methods that have been developed to fit observed data to model functions. We will review the most applicable of these techniques, including those that many in the crater community have not considered – a class of techniques known as "bootstrapping." These are a class of statistics that rely on random sampling with replacement, and they allow assignment of various measures of accuracy and do not...
require that the model function be "nicely" behaved.


**Figure 1:** Example population of impact craters identified on and around the *Apollo 11* lunar landing site by various authors (different symbols). Also shown is 3% and 5% of geometric crater saturation, and shown in grey lines are three different model crater production functions. Once the observed population data are fit to a model function by adjusting the vertical offset, a model age could be assigned.