CURRENT IMPACT RATE ON EARTH, MOON, AND MARS. A. McEwen[1] I. Daubar[2], B. Ivanov[3], J. Oberst[4], R. Malhotra[1], Y. JeongAhn[1], S. Byrne[1] [1]LPL, University of Arizona, Tucson, USA; [2]JPL, Pasadena, USA; [3]Institute for Dynamics of Geospheres, Moscow, Russia; [4]DLR and Technical University Berlin, Germany.

Introduction: Several recent datasets are measuring the current impact rate on Earth, Moon, and Mars:

1. bolide explosions in Earth's upper atmosphere
2. impact flashes on the Moon
3. New impact craters on Mars and the Moon

These new results (and older ones), as well as updated data on the orbital distribution of Mars crossing objects, should provide an improved basis for dating young planetary surfaces and they tell us about the meteoroid populations among the terrestrial planets.

There is significant interest in dating small and young planetary surfaces, such as late volcanic units on the Moon [1], Copernican craters, the Mars North Polar Layered deposits [2] and other terrains. Traditionally this is done using production function models based on crater counts from radiometrically dated lunar surfaces, which are then translated to Mars and elsewhere via a series of scaling assumptions [3, 4]. The production function for small craters depends on crater counts over the ejecta or interiors of a few young craters with exposure age dates from Apollo samples. There are numerous difficulties with this approach, including the effects of secondary craters [5] or putative self-secondaries over the ejecta [6], the sensitivity of small craters to varying target properties [7, 8], and unknown temporal/spatial fluctuations in the meteoroid population and associated impact rate.

In principal, direct measurement of the current impact rate provides a solid datapoint to calibrate the traditional production functions, and could be used directly as a production function applicable to extremely young terrains where small craters dominate. However, in practice each dataset comes with unique issues and uncertainties.

Earth bolide events are detected by classified U.S. satellite missions that are monitoring for missile launches or re-entries. Since the Chelyabinsk event an agreement was made to release these data to the NASA science community. A map of 556 bolide events from 1994-2012 is available from http://neo.jpl.nasa.gov/news/news186.html, with specific information on those events since Chelyabinsk (Feb 2012) available at http://neo.jpl.nasa.gov/fireball/. According to an email from Lindley Johnson (NASA) the rest of the data is being reviewed for release, hopefully in early 2015. However, information on the completeness of the monitoring is probably not releaseable, so this dataset provides only a lower limit on impact events. There is probably a size bias to the data, such that small events are missed more often than big events.

In addition, ground-based "fireball" networks monitor local areas for large bolides. These fireball observations allow us to precisely determine the dates for each impact and reveal whether or not they are members of known meteoroid streams.

Lunar seismic data obtained by the Apollo seismic station network allowed us to monitor the impact flux of large meteoroids continuously for more than 7 years [9]. This record of the lunar impact flux also revealed statistics of showers and sporadic meteoroids.

Lunar impact flashes are observed by several groups, the most complete from MSFC [10] with over 300 impacts since 2006. Luminous energy is used to estimate kinetic energy, and the correlation with known comet showers leads to velocity and mass estimates. Crater sizes can be estimated based on standard lunar regolith properties, calibrated in at least one case by LROC imaging of the resulting 18-m crater [11]. Like the seismic data, the impact flashes show correlation with comet showers, while other workers have concluded that asteroids strongly dominate the impact statistics of the inner Solar System [3, 4]. The impact flash data are limited to not-illuminated parts of the lunar nearside, which may introduce bias.

New martian craters (almost 500) have been documented in before-and-after images from multiple cameras [12-14]. This work has led to a new crater production function, which agrees surprisingly well with the traditional models, crossing near ~50 m diameter. However, the slope of the size-frequency distribution (SFD) is significantly less steep (smaller negative exponent to linear power-law fit) than the models, which may be due to atmospheric effects, lack of completeness, or inclusion in the models of unrecognized secondaries. If this represents the actual production function of today and if that trend extrapolates to larger crater sizes [cf. 2], the implication is that the current cratering rate is elevated over the historic average for larger sizes—we are in an impact spike. If true, that would make already surprisingly young surfaces even younger. From the model of [15], atmospheric deceleration could explain the shallower slope, and should vanish for craters with D>50m. Unfortunately all of the observed new craters are smaller than 50 m and we cannot yet measure the Martian SFD of D|>50 m.

The age implications drawn from this present-day SFD can differ greatly from those drawn using the lunar-based model SFD for small craters on very young terrains. For example, the SFD of small (diameter 40-400m) craters on the martian North Polar Layered Deposits follows the same shallow slope as [12-14] and so could be interpreted as an extremely young (10^3 yrs) primary population [2]. However, crater removal at a diameter dependent rate can yield the same population over much longer timescales (10^4 yrs) using the model SFD [16]. Simulations of crater removal through ice infill will offer a way to distinguish between these scenarios.

Densities of martian bolides: For single new martian craters (no atmospheric breakup) the model of ordinary chondrites results in a good fit to the observed SFD [17]. About half of the new martian impacts are clusters of craters, from bolides breaking up in the thin martian atmosphere. From the dispersion of the craters the densities of the bolides are mostly (~95%) in the range from 1100 to 2400 kg m^{-3} depending on the breakup altitude and the separation efficiency coefficient [15]. Cometary origin of some low density meteoroids cannot be excluded.

Observations of Mars crossing objects (MCOs) provide the orbital distribution of the current impactor population that is now nearly complete down to absolute magnitude 16. This allows direct computation of the frequency of large impacts. Computing the frequency of observable small impacts requires extrapolation of the magnitude/size distribution to meter-sized impactors. At the current epoch, Mars' eccentricity is near its maximum value (over its secular cycles). Consequently, a significant seasonal variation of the impact flux is expected and should be detectable with the data of new Martian craters, if the meter-sized impactor population shares the orbital distribution of the bright MCOs [18].

New lunar craters have been observed by the Lunar Reconnaissance Orbiter Cameras (LROC), from comparison to grainy (photographic) Apollo Panoramic images from ~40 years ago in a few cases [9], and with many more new impacts found from LROC-LROC comparison [19]. The challenge of the LROC dataset is distinguishing primary from secondary craters. New impacts create secondaries on Mars in some cases, but they are in radial lines from the primary crater (or tight cluster of primary craters), elliptical when resolved, and obviously secondaries because new impacts are so widely dispersed across Mars relative to secondary distances, and time constraints are tight enough to differentiate most impacts that are spatially near each other. However, impact velocities are ~2x greater on the Moon than Mars (or more, if cometary impacts are more common at Earth/Moon), and g is ~60% smaller, resulting in much more widespread secondaries on the Moon. Also, the LROC NAC images cover narrow swaths and repeat coverage is sparse. Because the time constraints are fairly wide, it is possible that many of the new changes seen on the Moon could have been caused by just a few discrete events. As a result, the majority of new dark or bright spots could be from secondary impacts [20]. There are clearly hundreds of secondary spots (albedo changes with no resolved crater) associated with one well-documented 18-m new crater [11], whose flash was first observed from MSFC [10].

Comparisons and Questions. By the time of LPSC 46 our hope is to reduce and normalize these datasets to comparable units, to begin to address a series of questions:

1. What is the current cratering rate and "slope" of the SFD?
2. What is the Moon/Mars cratering ratio for 10-30 m craters?
3. Are most present-day impacts from comets or asteroids, and how does that vary between Mars and Earth and with bolide size?
4. Are most of the new lunar impact spots primaries or secondaries?
5. To what degree can we trust any present-day SFD as the true present-day production function to date very young terrains?

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