REVOLUTIONIZING OUR UNDERSTANDING OF THE EVOLUTION OF MARS AND THE HISTORY OF THE INNER SOLAR SYSTEM. F. S. Anderson[1], T. J. Whitaker[1], and J. L. Levine[2], [1]Southwest Research Institute, 1050 Walnut St, Boulder CO; anderson@boulder.swri.edu, [2]Colgate University, Hamilton, NY 13346.

Introduction: The next Decadal Survey should advocate for new chronology missions for Mars, building on the results of Mars Sample Return (MSR). The Mars Exploration Program Advisory Group has established a key goal of "Understanding the origin and evolution of Mars as a geological system" (MEPAG Goal 3 and subgoals therein [1]) and is a component of one of the most important goals of planetary science: understanding the history and duration of events in the solar system, in order to place the evolution of life, and humanity, in context [2].

Unfortunately, the timing and duration of geologic processes on Mars, and throughout the inner solar system, suffer from uncertainties that are much larger than commonly acknowledged. The geologic history of Mars, and the inner solar system, is extrapolated from models of lunar impactor flux, crater counts, and ~270 kg of lunar samples analyzed and dated in terrestrial labs. However, the lunar samples primarily constrain the era from 3.5-4 Ga. For terrains younger than 3.5 Ga, uncertainties exceed 1 Ga [3]; specifically, ~3.5 Ga terrains may be 1.1 Ga younger. For Mars, additional problems are caused by uncertainty in "...the ratio of Mars to moon impact rates", which results in "...absolute ages on Mars [that] are only good to a factor of 2 to 4" [4]. For example, the range in estimated terrain age for the Amazonian period varies by nearly 700 Ma, not including the potential uncertainty of 1.1 Ga from the Moon [5-9]. Clarifying the relationship between impactor flux and surface age will require obtaining new dates from multiple terrains with a variety of crater densities. These new constraints will provide regional geologic insights as well as global constraints on crater density and age, and finally, enable new models of solar system flux and the surface age of other planetary bodies, such as the Moon.

Importance: These issues can lead to important changes in our understanding of the history of the solar system, and and hence the environment within which life evolved. For example, if new lunar crater counts based on better high resolution imaging derived from the Lunar Reconnaissance Orbiter Camera are accurate, then numerous consequences arise, including (1) the extension of the era of volcanism on the Moon and Mars by up to 1.1 Ga, (2) extending the end of the era of water on Mars by up to 1.1 Ga, and (3) that life arose on Earth not during a period of impact rate diminution, but instead during a period of bombardment twice as high as previously recognized. Following previous work, refinements in cratering flux will furthermore be propagated to Mercury [e.g., 10, 11], Venus [e.g., 12, 13, 14], Earth (where the record of ancient impacts has been erased by erosion and plate tectonics [15]), and models of early solar system dynamics [16].

Approaches: There are two complimentary approaches to improving our current understanding of solar system history. The first is the return of samples for in-/organic analysis and dating on Earth using the exquisite precision and range of current and future laboratory instruments. However, a limitation of this approach is caused by the need to sample a wide range of terrains, ultimately requiring many sample returns. After all, Apollo will likely remain the best sample return mission ever, yet the most important decadal survey goals for the Moon focus on the obtaining more samples for dating [2]. Given the great cost of sample return missions, the Decadal Survey explicitly supports in-situ dating [2], with a goal of ±200 Ma or better described in the NASA Technology Roadmap [17].

Methods: In order to support future Mars missions, we have developed an instrument called the Chemistry, Organics, and Dating EXperiment (CODEX) that interrogates hundreds of locations on a sample surface in a 2D grid using three modes: A) laser ablation mass spectrometry to measure elemental abundance, B) two-step laser desorption/ionization mass spectrometry to measure organics, and C) laser desorption resonance ionization mass spectrometry to measure rubidium-strontium geochronology. CODEX produces images of the spatial distribution of chemical elements and organics, and determines the isochron age of the sample. Understanding the rates of change for planetary processes (such as the history of water, climate, and potential biology) as well as providing a new understanding of impactor flux for the inner solar system requires multiple new spatially diverse absolute dating measurements.

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