IMPACT EXPERIMENTATION AND THE MICROGRAVITY ENVIRONMENT: AN OVERVIEW

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Impact is an ubiquitous physical process in the solar system. It occurs on all solid bodies and operates over a spectrum of scales, influencing geologic processes ranging from accretion, the early evolution of planetary bodies, the petrogenetic and spatial relations of lunar samples, the surface characteristics and interpretation of spectral data of asteroidal bodies, to the nature of some meteorites. Understanding impact phenomena is therefore paramount in constraining and underpinning a large number of research efforts into fundamental problems in planetary geology. Gravity is an important parameter in impact processes. For example, in cratering it affects the size of crater excavation, the post-excavation modification of the cavity by gravitational collapse, the spatial distribition of ejected materials, and the effectiveness of this ejecta in producing secondary cratering events. With few exceptions (Gault and Wedekind, 1977) previous experimental studies of cratering processes have been undertaken at gravitational accelerations of 1g or higher. These are not the gravity conditions occurring on most solid bodies in the solar system. The physical environment offered ultimately by Space Station represents an unique opportunity to extend the experimental aspect of impact studies into the microgravity (<1g) regime.

Previous and current experimental studies of impact phenomena address a variety of problems. The bulk of impact experimentation, however, has been concerned with crater growth and scaling. Experimental data have established that at impact energies above ~10^{18}-10^{19} ergs (equivalent to the impact of an iron meteorite in the meter-size range impacting at 20 km s^{-1} in a 1g environment), crater excavation occurs in the so-called "gravity regime", where target strength effects are unimportant (Schmidt, 1980). This condition is simulated experimentally by using low strength materials, such as sand or water, and by the use of elevated gravitational accelerations. The effect of elevated gravity is to displace the onset of the gravity regime to lower energies. Such experimentation has led to the development of scaling relations, where cratering efficiency is related to a dimensionless parameter which includes the effects of projectile velocity and size, and gravitational acceleration.

It has been sugggested recently that additional parameters such as the shape of the experimental projectile (Schultz and Gault, 1985) and variable energy losses due to waste heat in the target (Cintala and Grieve, 1984) are not fully accounted for in the current dimensionless parameters. Thus it is important to continue work in this area. The opportunity to conduct new experiments at gravities directly applicable to that of planetary bodies will contribute to determining and refining the relevant scaling relations for large craters. Apart from their importance in problems concerned with cratering mechanics, such relations are required to correctly relate crater densities on different solar system bodies to absolute surface ages (Basaltic Volcanism Study Project, 1981).

A further advantage of the microgravity environment is that, for a given impact event, reduced gravity increases the crater growth time. It will be possible, therefore, through high-speed photography to observe the crater growth and ejecta dynamics in considerably more detail than in previous 1g experiments. This will lead to a better understanding of the relative importance of rebound and collapse phenomena in crater formation and the nature of the ejecta plume as an erosional and depositional agent.

In the low strength materials used in impact experiments under terrestrial conditions, gravitational forces dominate other bonding forces, such as surface tension, electrostatic effects etc. This may not be the case under highly reduced gravity conditions, which prevail on small asteroidal bodies. Even if current dimensionless scaling relations are shown to be substantially correct for large planetary craters, they can not be applied to the energy regime associated with small cratering events. Cratering experiments at highly reduced gravities, corresponding to asteroidal bodies, will therefore provide basic and currently unavailable information on cratering and regolith development or lack of it on these bodies.

Previous experimentation provides little or no information on the spatial distribution, source region and physical state of ejecta under differenct gravity conditions. The few experiments designed to address these fundamental questions all have been undertaken at 1g (Stoffler et al., 1975). Similarly, the only direct observational data on these questions are from terrestrial craters. It is well-established that for a specific impactor size and velocity and target materials, crater size will increase with decreasing gravity. However, peak shock pressures and the spatial distribution of shock isobars in the target are not a function of gravity and will remain constant. They are a function of impact velocity, pulse length and target characteristics. The reduced gravity environment afforded in near-earth orbit provides an opportunity to consider the questions of ejecta source and shock state and its final distribution under varying gravitational accelerations. These questions are highly germane to problems such as the physical and thermal state of ejecta blankets and regolith development on both planetary and smaller bodies. These relate directly to questions in lunar sample and meteorite analyses and the interpretation of remotely-sensed spectral and geochemical data.

The microgravity environment also provides a new and potentially rewarding area of impact experimentation not previously possible. Through the use of free-floating targets, it may be possible to explore in detail phenomena associated with the collision of bodies. Such experiments can address questions regarding early and late accretional processes, catastrophic disruption and asteroidal evolution, as well as the effects of large impacts on the momentum and spin of the target bodies. The last question is of considerable topical interest with respect to the hypothesized origin of the moon by a Mars-sized impact on the early Earth.

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