https://ntrs.nasa.gov/search.jsp?R=19890005662 2020-03-20T04:54:24+00:00Z

N89-15033

# DEBRIS-CLOUD COLLISIONS: ACCRETION STUDIES IN THE SPACE STATION

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Background: The growth of planetesimals in the Solar System reflects the success of collisional aggregation over disruption. It is widely assumed that aggregation must represent relatively low encounter velocities between two particles in order to avoid both disruption and high-ejecta velocities (1,2). Such an assumption is supported by impact experiments (3) and theory (4). Experiments involving particle-particle impacts, however, may be pertinent to only one type of collisional process in the early Solar System. Most models envision a complex protoplanetary nebular setting involving gas and dust. Consequently, collisions between clouds of dust or solids and dust may be a more realistic picture of protoplanetary accretion. Recent experiments performed at the NASA-Ames Vertical Gun Range (5) have produced debris clouds impacting particulate targets with velocities ranging from 100 m/s to 6 km/s. The experiments produced several intriguing results that not only warrant further study but also may encourage experiments with the unique impact conditions permitted in a microgravity environment.

Collisions Between Debris-Clouds and Particulate Surfaces: Impact experiments at the NASA-Ames Vertical Gun Range have assessed differences between clustered and single-body impacts on particulate surfaces. The primary goal was to examine the effects of atmospheric entry on cratering and possible implications for secondary cratering processes (5). Impacting debris clouds were produced during passage of a brittle pyrex projectile through a thin sheet of paper or aluminum foil. At hypervelocities ($v > 5$ km/s), a 2.5 mil sheet of paper was sufficient; at supersonic velocities ($v \sim 2$ km/s), a 1 mil aluminum foil was used. Because the launch tubes are rifled in order to induce separation between the projectile and sabot, the effective dispersion of the debris cloud could be varied by changing the distance between the target surface and paper or foil. High-frame rate photographs recorded the resulting dispersion in the impacting debris cloud and thus the effective density at impact.

The experiments revealed a factor of 5 decrease in predicted cratering efficiency for an impact by a solid projectile of the same mass (m) and velocity (v). If the energy density of the impacting cloud is included (6) by using a dimensionless expression of cloud radius (r) divided by $v^2$, then cratering efficiency is only slightly decreased. As might be expected, the crater aspect ratio and morphology were significantly altered (5). As typical for laboratory experiments, however, several unexpected phenomena also occurred. First, the high frame-rate photographic record revealed an intensely luminous cloud immediately after impact (7). The early stages of ejecta-plume growth were characterized by an amorphous cloud rather than the systematic expansion of a funnel-shaped curtain typical for single-body impact. Second, unusually large (1-5 cm across) fairy-castle aggregates were produced. Many of these aggregates had low-ejection velocities. An impact by a 0.2 g/cm$^3$ cloud at 4.1 km/s produced an unusually large aggregate extending from the floor to above the crater rim. The exact nature of such aggregates is not yet known; they appear to be melt-welded target material. We also do not yet know for certain if melt production increased relative to a single-body impactor. The early-time film record showing a bright luminous cloud and the slight decrease in cratering efficiency, however, may be indicating greater partitioning into internal energy losses. These preliminary results would indicate that collisions between two debris clouds might produce aggregates, thereby increasing particle sizes, whereas a single particle impacting a particle results in disruption and comminution. Such an experiment could provide new insight for early planetary growth processes and for interpreting the record of this stage (e.g., 8,9).

Possible Space Station Experiments: The microgravity environment of a Space Station would allow detailed studies of the competing processes of aggregation and disruption using conditions more appropriate (or at least scalable) for an evolving protoplanet. A cloud of impactor fragments can be readily produced in a manner already performed on Earth, but of different density, composition, and initial size distribution. Of specific interest would be the change in size distribution, shock state, velocity distribution, mixing, and the possible production of chondrite breccias (10). The formation of chondrules is more equivocal (10) but objections could reflect an incomplete experimental simulation. Collisional velocities would range from values expected for collisions in a nebular disk (< 100 m/s) to values possible from the early stages of planetesimal growth (<6 km/s). Perhaps the most intriguing aspect is the capability of repetitive collisions and more unusual conditions, e.g., passage of a larger projectile through a suspended debris cloud. The latter experiment could be performed over long path lengths by tubular extensions from the proposed impact facility.

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