EXPERIMENTAL AND THEORETICAL EXAMINATION OF COSMIC DUST GRAIN DECELERATION. W. G. Tanner[1,2], W. M. Alexander[1], and S. Stephenson[1]. [1]Baylor University Space Science Laboratory, Waco, TX 76798 USA, [2]University of Kent at Canterbury, Unit for Space Science, Kent CT2 7NR, UK

OVERVIEW: During the past few years several designs for devices to detect the penetration of a thin metallic film by a dust grain have been tested both in the laboratory and in space. Another crucial component of the analysis has been the theoretical calculation conducted to assess the parameters of the hypervelocity penetration event. In particular theoretical hydrodynamic calculations have been conducted to simuated the hypervelocity impact event where various comsmic dust grain candidates, e.g., ρ = 7.87, 2.70, 1.00, have been utilized to reproduce the events. Theoretical analyses of hypervelocity impact events will be reported which span an extensive matrix of values for velocity, density and size. Theoretical deceleration values have been duduced from the data created by CTH, a Sandia National Laboratory Hydrodynamic computer code (McGlaun et al, 1990). The calculation of the pressure, temperature, and density of the impactor during the high shock events have also been assessed. With these data one can assess the thermodynamic behavior of the material in the interaction, and connect thermodynamic properties in the impactor with the deceleration process.

BACKGROUND: The plasma yielded by the hypervelocity penetration events has been collected and an empirical power law fit made to the normailized data (according to the paritcle mass). That data also may be utilized to assess the deceleration of cosmic dust grain analogs which penetrate the flim and impact the stopping plate or capture foam. A siginficant quantity of data has been taken which illustates the change in the velocity of a dust grain after it has penetrated an ultra thin film. A continuing effort to model hypervelocity impact penetrations has yielded an extensive matrix of data for penetration events consistent with the experimental data. The primary goal of these research efforts has been to establish unequivocally a semi-empirical equation which can relate the penetration hole diameter, D_h with the penetrating particle diameter, D_p. The velocity of the particle will be a parameter of special importance and for theat reason a study of theoretical limits on the deceleration of dust grains has been undertaken. Perhaps the most important results of simulated particle passage through the test films has been the theoretical confimaton of the degree of destruction a cosmic dust grain experiences.

PENETRATION MECHANICS: The principal theoretical approach has been to perform calculations using a hydrodynamic computer code CTH. This tool provides a computational laboratory where hypervelocity impacts may be controlled and observed. The complete perforation of a thin film will create a significant amount of data depicting the event. The most useful utilization of the modelled event has been the determination of the hole size generated by the penetrating dust grain. Provision must be made of the most crucial parameter which controls the simulation, i.e., time to maximum expansion of the penetration hole. That time must be commensurate with the expansion of the shock front and the rarefaction wave. Pressure, density and temperature in the film must also be tracked to assess the progression of the energy in the material. Of equal interest is the strain rate which signals the relaxation of the material following the passage of the shock front through the material. Once the strain rate has reduced in value near the walls of an impact site a commensurate decrease is seen in the other extensive variables of the interaction, and thus confirm that the progression of the crater's diameter has been halted. Penetration mechanics suggests that the more that the diameter of the impactor exceeds the thin film thickness the less will be th erosion of the projectile during passage through the film. Thus, Dp / Tf must be maximized in order that the fragmentation of the dust grain may be minimized. Hydrodynamic computer programs have benefited greatly from the data provided by many experiments designed to assess the effects of high-shock conditions present in materials. Principally the "hydro-code" calculations possess equations of state which describe both the elastic-plastic and the phase transition with melt of the high-shock regime. For several years research has been underway to assess the association between specific thermodynamic properties of materials and the process of fragmentation, i.e., the catastrophic failure of materials. Using CTH, many properties of hypervelocity particle thin film capture techniques have been theoretically analyzed. Hypervelocity perforation of thin films will fragment glass spheres which have been used to simulate Interplanetary Dust Particles (IDPs). Upon impacting a thin film with hypervelocity a small IDP analog will fragment if and only if the film thickness and the IDP analog's velocity are sufficient. Hence the coupled parameters of velocity and D_p / T_f ratio will determine the degree of fragmentation the thin film will cause in the IDP analog. With a hydro-code calculation one can investigate many different values for velocity and film thickness. CTH has been used to investigate the penetration mechanics of small particles impacting and perforating a thin film. The fragmentation of IDP analogs have been investigated to determine penetration parameters of thin films. The same analysis can be applied to the fragmentation of targets or projectiles or even secondary impacts due to ejecta sprays.

EXPERIMENTAL RESULTS: Results of both two-dimensional (2D) computer simulations of the hypervelocity impact events which penetrate the STS and the EuReCa 1 thin films will be reported. A relationship between the particle diameter, D_p, and the diameter, D_h, of the hole created in a 500 Å aluminum thin film (T_f) for relevant particle and target parameters will be derived and will be compared with empirical equations. That relationship will be used to analyze *in situ* data of the thin film experiments flown in LEO, and to determine the size distribution of grains which penetrate the thin films [2]. Charge liberation events due to hypervelocity impacts which have penetrated an ultra thin film (Al 250Å and 500Å) and are captured in an underdense foam. The velocity of the dust grain allows for the determination of the mass of an assumed sphere. Efficient charge collection immediately in front of the thin film is the result of a focussing potential of -45 volts on the grid wires. The charge collected reflects an jet initiation event and thus will be most pronounced on the front side of the thin film. Charge collected behind the thin film is much more diffuse and thus is broader in time. It should be apparent that the impact into foam liberates charge in excess of the charge measured at the rear of the film. A time of flight between the thin film perforation and the foam impact can be analyzed to determine a change in the velocity of the perforating dust grain. Charge liberated from the carbon containing material in evidence by the excess of charge on the charge collection grid immediately in front of the foam. The proposed ultra thin film experiment has been tested in the laboratory to establish the quantity of charge liberation during an intact capture event. The entire ultra thin film system has proved to be mechanincally sound after experiencing the launch loads of the Shuttle. Also after eleven months exposure to the LEO space environment the HVI/BUSSL 500Å aluminium films exhibited no penetrations due to mechnical effects. Theoretical calculations have facilitated the determination of the penetration efficiency of the thin film materials selected. Subsequent laboratory studies as well as analysis of the thin film experiment flown on EuReCa have demonstrated the optimization process has produced a highly successful combination of materials. These tests constitute an initial calibration of the thin film charge detection system which will provide data depicting the dynamics of grains COMRADE, SOCCER or LDEF II will collect.

CONCLUSION: Data will be utilized to assess the deceleration of cosmic dust grain analogs which penetrate the flim and impact the stopping plate or capture foam. These data which illustate the change in the velocity of a dust grain after it has penetrated an ultra thin film will be compared with theoretical calculations produced by CTH. Of equal importance will be the comparison of thermodynamic properties of a cosmic dust grain analog with those data generated by theoretical calculations.

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