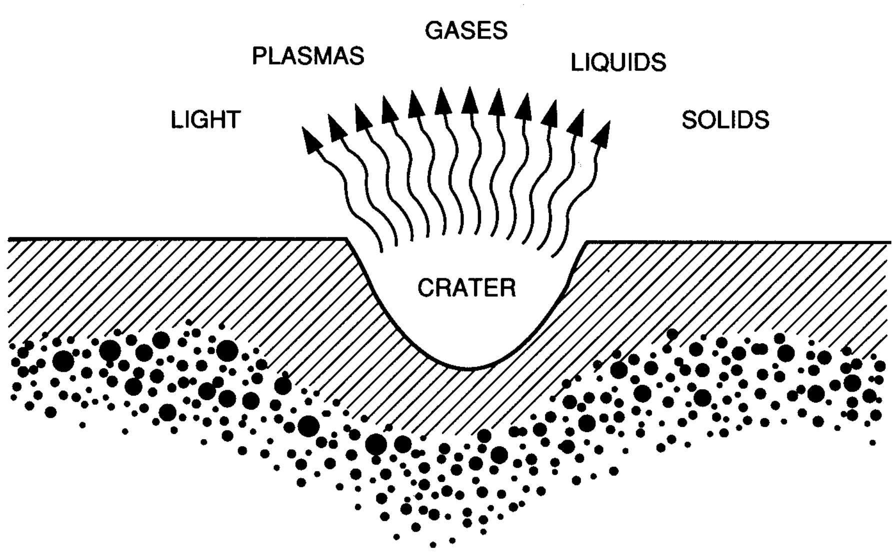
Microprojectiles: Speeding Cosmic Dust

When European and Soviet satellites were launched to rendezvous with Halley's Comet in 1986, scientists placed impact detectors on board to measure the density of the comet dust. The comet's velocity was so much greater than that of the satellites that the dust particles "exploded" on impact, vaporizing parts of the detectors and blasting craters in them. Damage to the detectors was one record of the intensity of the comet dust. The physical phenomena responsible for the collision dynamics of those tiny dust particles also played a part in the much larger projectile impacts that formed the craters on the Moon and other celestial bodies. When a projectile is traveling at such a high velocity that the release of its energy near the target surface is considered to occur instantaneously, the collision is called a hypervelocity impact. Understanding the basic physics of such impacts is the goal of research we began this year.

We are conducting "comic dust" experiments at the new hypervelocity impact research laboratory, a modification of the existing 6-megavolt vertical Van de Graaff accelerator. In the Van de Graaff, we use high voltage and a long vacuum tube to accelerate charged spheres of carbonyl iron to tremendously high speeds. This year we achieved a breakthrough by accelerating specks of iron no bigger than the particles in a cloud of smoke to speeds above 30 kilometers per second, or more than 70,000 miles per hour. Building on contemporary experiments with less powerful accelerators at universities in West Germany and England, we are duplicating in the laboratory, in a previously inaccessible velocity range, the complex physical phenomena that occur during hypervelocity impacts.

Consider, for example, what happens when an iron meteorite traveling 100 kilometers per second slams into a stone planet. The impact of the meteorite compresses an area of the planet and generates shock waves. In the unloading, or relaxing, of a solid body so compressed by a strong shock wave, the material encompassed by the wave is completely vaporized if the energy behind the wave front is many times greater than the energy binding the material together. In this case, each iron atom in the meteorite carries with it a kinetic energy of 3,000 electron volts, while the energy required to vaporize one molecule of stone (depending on the stone's composition) is only about 6 electron volts.

We can estimate that each incoming iron atom converts about one hundred molecules of stone into gas, a process that uses up about 20 percent of the atom's kinetic energy. But as the energy behind the shock wave dissipates and falls below about 50 electron volts per atom, it no longer vaporizes the stone completely. We know that part of this remaining energy is expended in melting, pulverizing, and ejecting some of the stone, forming a crater ten to thirty times the size of the meteorite. And we know that part of the energy is converted to light, x rays, and weak shock waves. Until now, however, scientists have not determined precisely what goes on during a hypervelocity impact; consequently, it has been difficult to obtain even a reasonably accurate analytical description. To provide such a description, Science Applications International Corporation, under contract to the Laboratory, is programming the known phenomena on a computer and calculating the numerical results. We will compare the calculations with the data from our experiments to see how well the computer code describes the physical phenomena. The code will then be refined.



Types of ejecta removed from a target bombarded by hypervelocity projectiles.

The first task is to obtain more experimental data describing what happens when our cosmic dust strikes a target at velocities of 50 kilometers per second and higher. A particle traveling that fast carries with it enough kinetic energy to vaporize target atoms representing many times its own mass. Indi-

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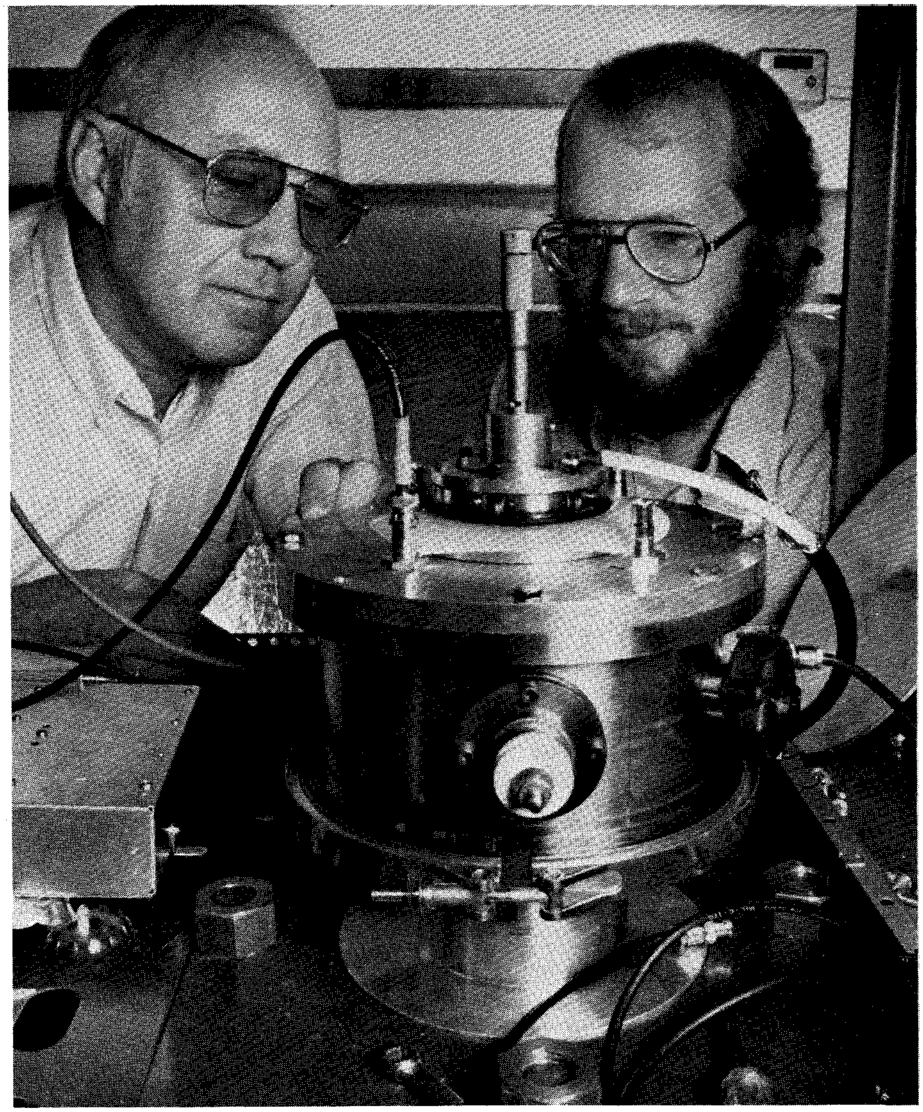
vidually, the vaporized atoms are very light, but they are ejected from the target in such quantity that, like tiny jets, they add to the momentum imparted to the target by the impact. This "momentum enhancement factor" varies with differences in particle velocity, target material, and impact angle.

Measuring the momentum enhancement factor is a central goal of our research, and we are developing sensitive techniques for obtaining the measurements. In addition, we are improving the particle-injecting mechanism, the target chamber, and the electronics. When we have refined the equipment, we expect to be able to accelerate particles to 100 kilometers per second. To test the physics of particles of various densities, we will eventually experiment with aluminum, tungsten, and even gold dust.

Space technologists will find our experiments useful because the results may answer such questions as whether micrometeorites could damage a space station by pitting its windows and other exterior surfaces or by slowing it in its orbit. Our work has potential applications for the nation's Strategic Defense Initiative programs as well. Suppose, for example, that an attacker initiates a nuclear exchange by launching an intercontinental ballistic missile that can deploy ten warheads. To camouflage the weapons, the attacker replaces one of the warheads with one hundred decoys, each weighing 1 percent of the warhead's weight. Now the booster will send not ten but one hundred nine objects-one hundred of them lightweight decoys-cruising through space in formation. The attacker's hope is that much of the strategic defense effort will be wasted on the decoys so that most of the warheads will get through to their targets.

But the defense knows that decoys are much lighter than warheads. Imagine the oncoming formation as a cloud of cannonballs- and toy balloons. Could one somehow blow at the cloud and so push the balloons out of the pattern? Researchers are investigating the concept of striking such an offensive formation with a field of dust particles that could "blow" the decoys off course by changing their velocity. The decoys would be nudged slowly away from the trajectory of the warheads, whose weight would prevent them from being affected by the dust, and the real targets would be exposed to the defenders.

How much dust would it take to do this? Here the momentum enhancement factor comes into play, for adding its thrust to the impact of the particles would enable the defense to employ a lighter dust payload. The objective now is to learn how much enhancement we can obtain for a given particle velocity. Our experiments are providing for the first time a means of answering this and other important defense and space science questions.



Paul Keaton (left) and George Idzorek prepare the cosmic dust source for installation on the Los Alamos 6-million-volt Van de Graaff accelerator.

Los Alamos

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