# Measurement of Meteor Impact Experiments Using Three-Component Particle Image Velocimetry

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The study of hypervelocity impacts has been aggressively pursued for more than 30 years at Ames as a way to simulate meteoritic impacts. Development of experimental methods coupled with new perspectives over this time has greatly improved the understanding of the basic physics and phenomenology of the impact process. These fundamental discoveries have led to novel methods for identifying impact craters and features in craters on both Earth and other planetary bodies. Work done at the Ames Vertical Gun Range led to the description of the mechanics of the Chicxualub crater (a.k.a. K-T crater) on the Yucatan Peninsula, widely considered to be the "smoking gun" impact that brought an end to the dinosaur era.

This is the first attempt in the world to apply three-component particle image velocimetry (3-D PIV) to measure the trajectory of the entire ejecta curtain simultaneously with the fluid structure resulting from impact dynamics. The science learned in these experiments will build understanding in the entire impact process by simultaneously measuring both ejecta and atmospheric mechanics. Furthermore, it will aid in the interpretation of the data coming from the Deep Impact Space Probe, due to be launched in 2004.

The work has implications not only to geologists but also to space transportation engineers. Micrometeorites that impact space vehicles may have catastrophic effects on those ships. Modeling these impacts has been an active field of study as well. As a matter of course, the experimental methods developed for the planetary geologist have been applied to the study of impactor effects on space vehicles and vice versa.

The first goal was to develop the PIV technique as applied to hypervelocity impacts and prove the concept. The second objective was to observe an impact, both to visualize and to quantify the extremely complex ejecta-gas interaction resulting from an oblique impact in an atmosphere.

The system was set up at the Ames Vertical Gun Range. As shown in figure 1, two cameras are mounted in a stereo arrangement above the target. A laser light sheet, 5 millimeters thick, was projected from the side and was oriented 3.5 inches above and parallel to the target surface. The laser creates two short-duration pulses with a controllable time interval (on the order of microseconds) between the pulses. The cameras record separate images of the ejecta as illuminated by the two laser pulses. The resulting image pairs from each camera were cross-correlated to determine both the direction and the magnitude of the displacements of the ejecta in the plane of the laser. The perspective difference of each

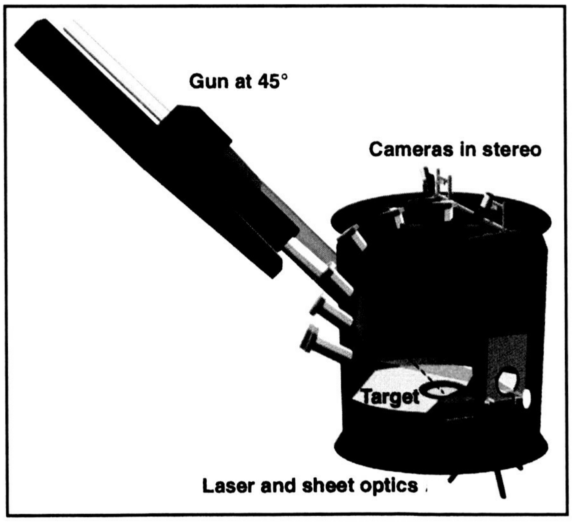


*Fig. 1. Illustration of the PIV system, the target, and the vacuum chamber of the Vertical Gun Range.*

camera view permits the derivation of the third component of velocity. Tracer particles were added to the target to follow the gas dynamics, thus permitting simultaneous cross-correlation with the ejecta.

The implementation of 3-D PIV yielded excellent results. Figure 2 shows a typical flow pattern derived from the PIV measurements. This vector and contour plot represents both the speed and direction of the impact dynamics resulting from a one-eighth-inch copper sphere traveling 2.2 miles per second. It impacted the surface of the sand target at 45 degrees. The atmosphere above the target was nitrogen at a pressure of approximately 7.5 pounds per square inch. The lengths of the arrows are directly proportional to the velocity of the particles in the data plane. The color represents a contour of the velocity component that is perpendicular to the data plane. The blue regions are moving away from the viewer; the orange regions are moving toward the viewer. Note that the ring of ejecta is distorted because of the angular impact. The downrange particles are moving significantly faster than other portions of the curtain. In addition to the ejecta ring, the fluid mechanics associated with the wake of the impactor are clearly shown.

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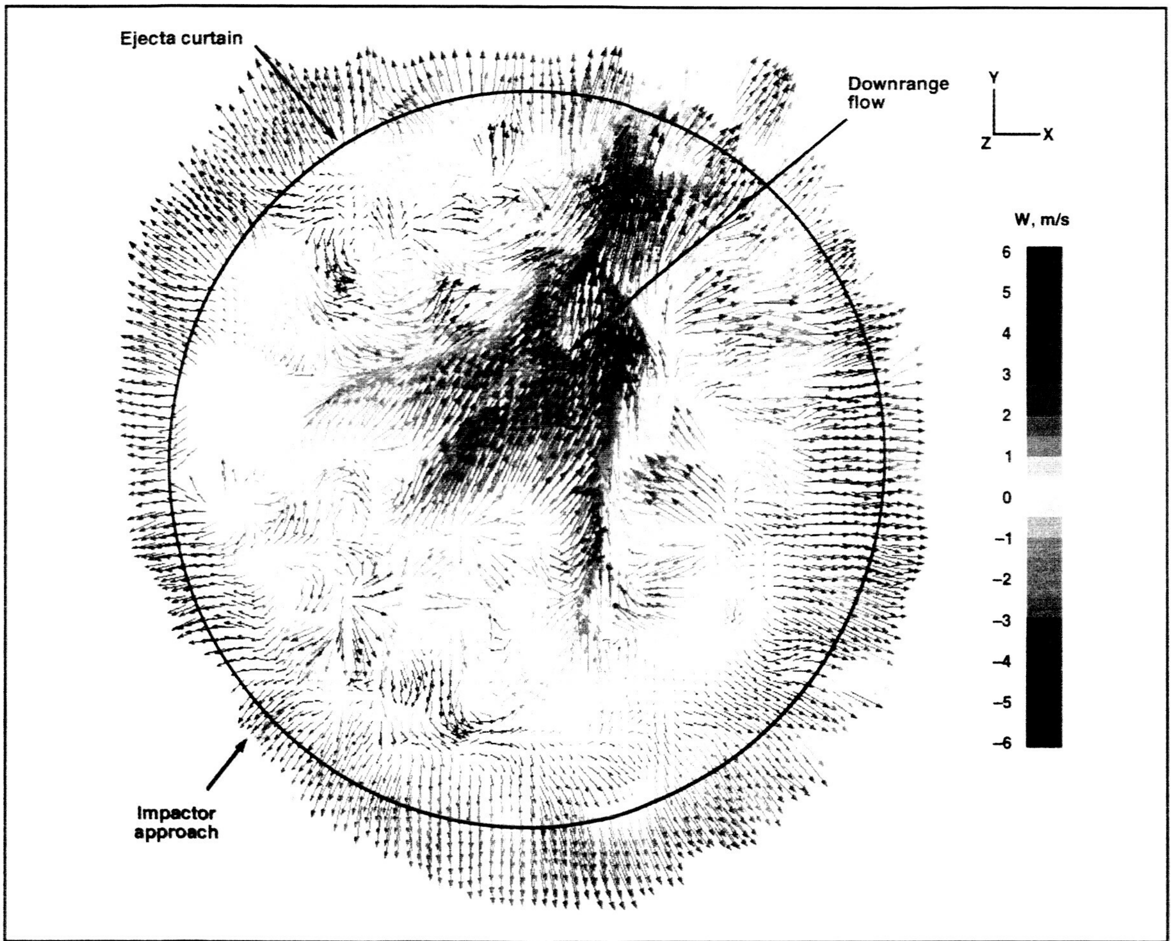


*Fig. 2. Vector plot of the in-plane velocities of impact ejecta and atmospheric interaction. The contour colors are of the out-of-plane velocities.*