During a mission or test, the I^2 Team provides oversight of imagery operations to verify fulfillment of imagery requirements. The team oversees the collection, screening, and analysis of imagery to build a set of imagery findings. It integrates and corroborates the imagery findings with other mission data sets, generating executive summaries to support time-critical mission decisions.

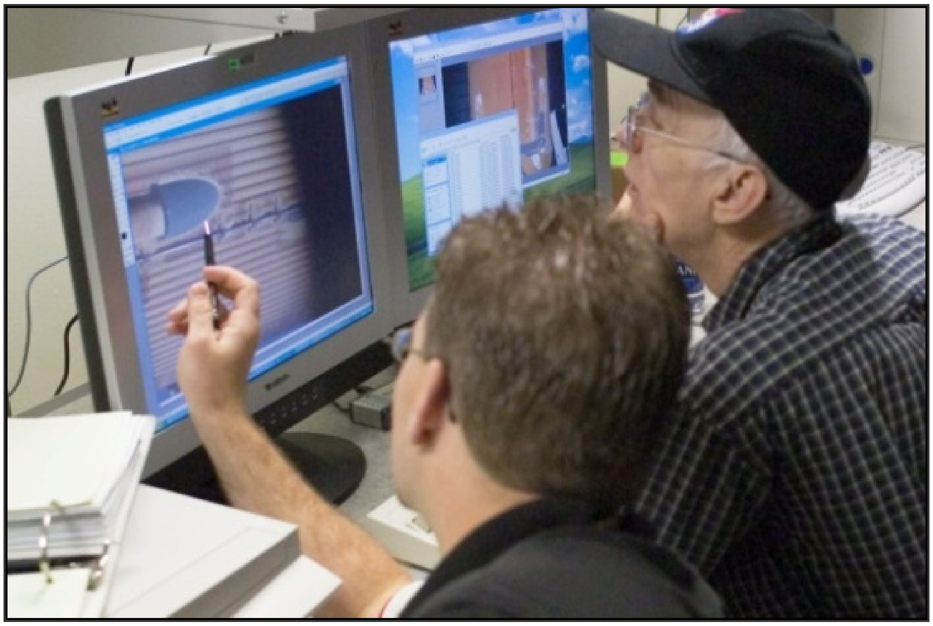

Figure 6.– Screening and analysis.

Advancements in Capsule Parachute Analysis

David Bretz

The Image Science and Analysis Group (ISAG), a subgroup within the ARES Directorate, has provided image analysis support of the Capsule Parachute Assembly System (CPAS) testing being conducted at the Yuma Proving Grounds by JSC Engineering. The work being done by ISAG is a continuation of photogrammetric analysis that began in 2010, which is expected to extend through 2014 with the development and analysis of parachutes for the Multi-Purpose Crew Vehicle (MPCV) being developed at JSC.

At the request of the engineers, ISAG developed methods for converting video imagery into parachute flight performance parameters, such as fly-out angles, parachute skirt diameters, and drogue mortar deployment speeds. This information (along with many other parameters measured with a variety of instruments) is used by engineers to understand and accurately model parachute behavior, drag coefficient, and rate of descent. Good models will improve the fidelity of MPCV simulations of roll control and splashdown impacts.

In the last 2 years, the tests have evolved to use more realistic drop test vehicles, such as the Parachute Compartment Drop Test Vehicle (PCDTV), which has a realistic parachute compartment but a long body and dart-shaped nose, and the Parachute Test Vehicle (PTV), which has a capsule shape to mimic the dynamics of the true MPCV (figure 1).

Figure 1.– (Left to Right) Images showing the PCDTV and the PTV.

The cameras installed on these vehicles have been upgraded from early testing and have expanded the role of photogrammetry. They now provide 60 frames per second (progressive) high-definition quality (1280 x 720 pixel) imagery of the main parachute during all phases of activity as well as 300 frames per second high-speed imagery of very dynamic events, such as the drogue mortar deployment, drogue inflation, main parachute deployment, and main parachute reefing stages. Characterization of the optical properties of these cameras, such as focal length and lens distortions, and the fine-tuning of the exposure settings have been important aspects of ISAG support during this period.

The methods of photogrammetric analysis have also evolved in technique and in the variety of investigations. Determination of the fly-out angles (angle between parachute center and centroid of the parachute cluster) and the main parachute skirt diameters has improved. Previous methods used features at the top of the canopy to provide direct scaling of image features, and while these methods corrected for lens distortion, they did not account for image distortions caused by the change in perspective as the parachutes fly out from the center of the cluster, tilting to the side in the wide field of view. A new method was developed to account for this wide perspective. The method, which requires no additional camera, assumes the parachutes move on the surface of a sphere of constant radius surrounding the camera because they are tethered to the vehicle (figure 2). The points on the video image that track the edge of the parachute are used to define vectors in space that intersect this sphere. This allows the points on the actual skirt to be located in 3D space relative to the camera, and these points can then be analyzed to determine the inlet area and diameter of each parachute canopy over time (figure 3).

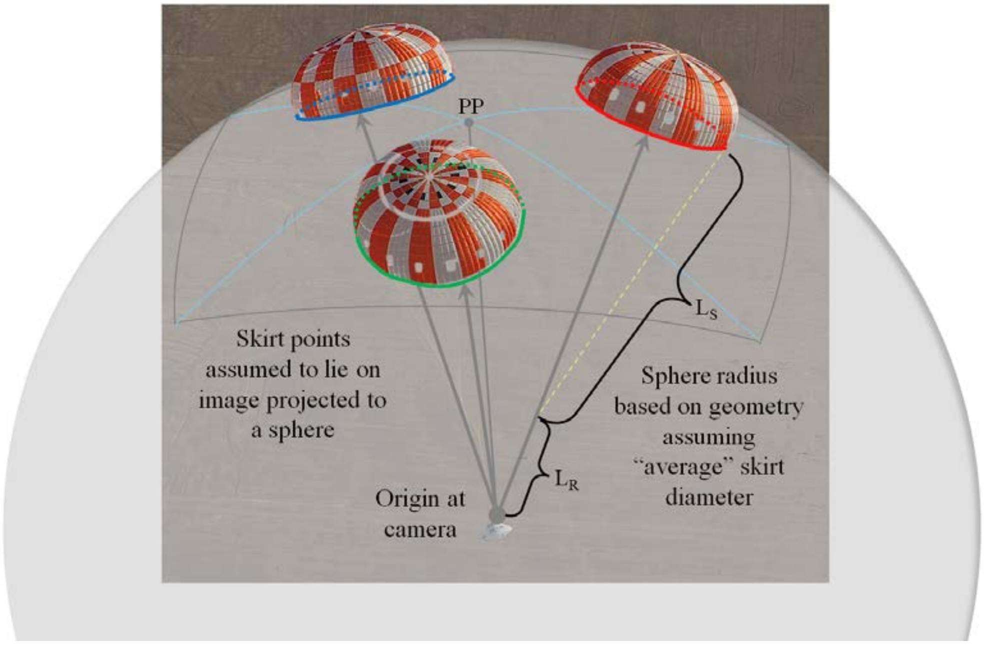

Figure 2.– Diagram illustrating how points on the main parachute skirts can be assumed to lie on the surface of a sphere centered on the vehicle. L_R and L_S are the lengths of the parachute riser line and suspension lines, respectively, which define the radius of the sphere when an average skirt diameter is assumed.

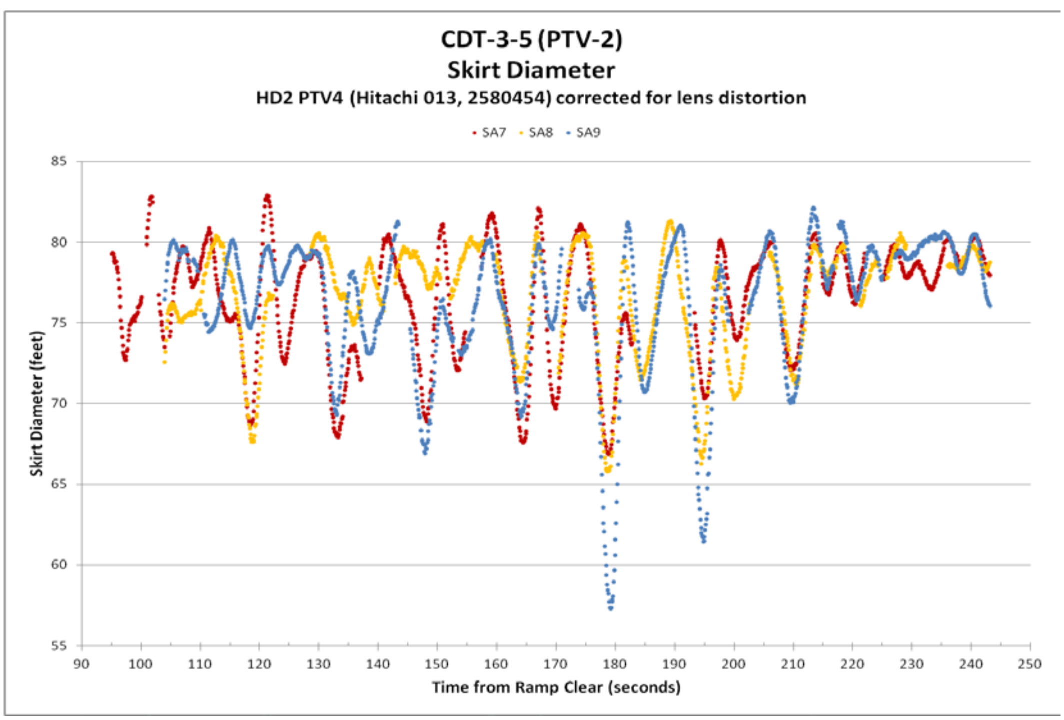

Figure 3.– Parachute diameters versus time for Cluster Development Test 3-5 (CDT-3-5).

A high-speed camera with a view of one of the two drogue mortars on each test has allowed measurement of the velocity of the drogue mortar as it exits and travels away from the camera. Figure 4 shows the early moments in the deploy sequence. The deployment bag containing the parachute is fixed to a rigid and circular mortar lid at the front. (A circular shaped sabot attached to the back of the bag falls away soon after ejection.) Points on the front lid are tracked, and the apparent diameter of the lid is calculated. Knowing the diameter of the lid and the camera's focal length allows the distance to the deployment bag to be calculated. The measurement method was verified by recording and analyzing similar images during a ground test at General Dynamics in early 2012. Figure 5 shows the mortar speeds measured for five tests.

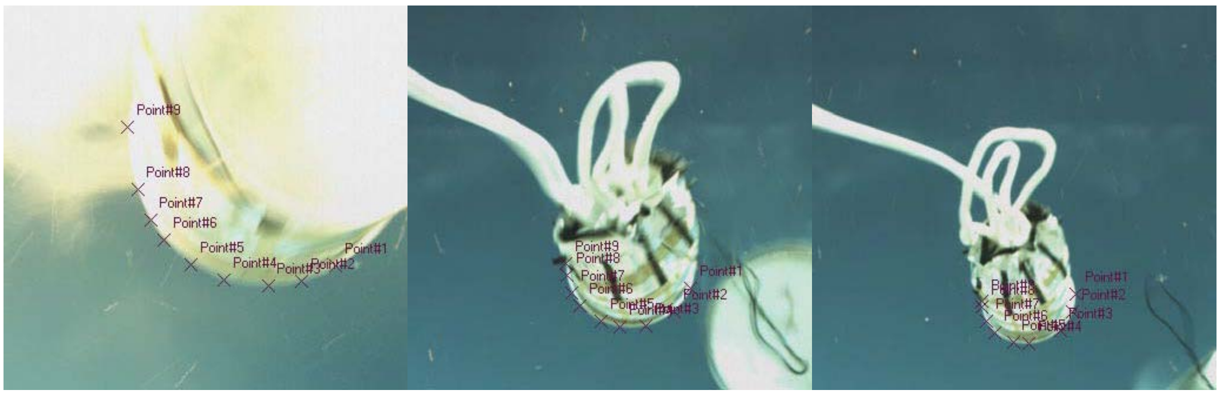

Figure 4.– High-speed camera images showing drogue mortar deployment on CDT-3-1. The rigid lid affixed to the front of the drogue deployment bag is used to measure distance while the sabot (back-facing lid) comes free and falls to the right.

Drop Test	Vehicle	Mortar Speed (feet/sec)	Distance Range for Speed Calculation (feet)
CDT-3-1	PCDTV	140	7-28
CDT-3-2	PCDTV	148	2.5-24
CDT-3-3	PTV	123	2.5-27
CDT-3-4	PCDTV	144	7-93
CDT-3-5	PTV	140	2.5-32

Figure 5.– Mortar speeds calculated using high-speed imagery recorded during drogue parachute deployment.

Current and future parachute tests (through 2014) will involve an analysis of parachute fly-out angles and diameters. Additional analysis of the dynamics of the main parachute bag deployment also will be performed.