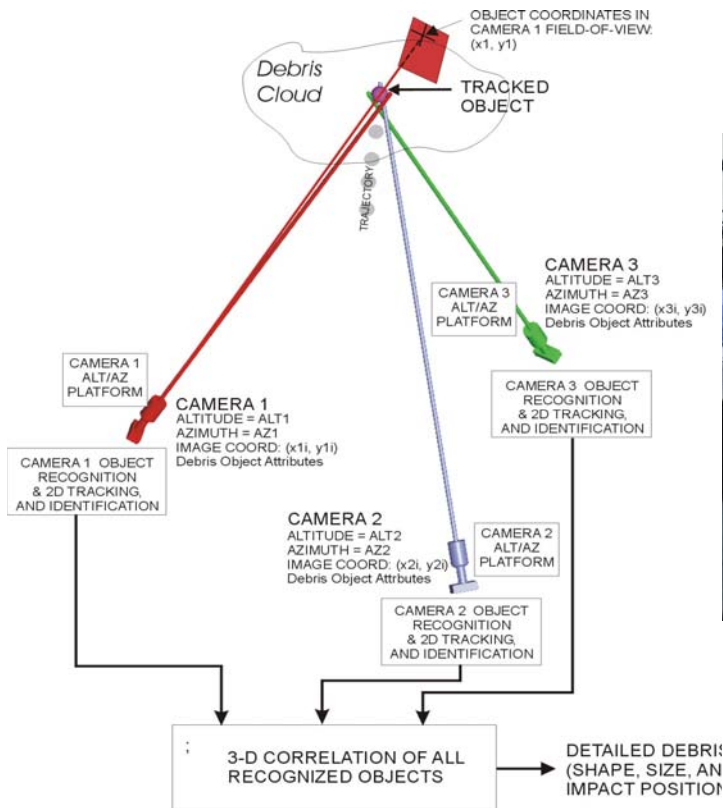


Advanced Multiple Object Detection in 3D

The Phase II Advanced 3D Multiple Object Detection program, funded by NASA, focused on the development of a digital imaging and tracking capability with two primary goals: to provide a means for tracking and predicting the trajectories of falling objects in three dimensions (and their eventual ground impact positions), and to provide a means for identifying such objects using rough geometric shape and size estimates. This scenario is depicted in the figure below. A complete system was built (also shown below) consisting of two independent tracking stations and post-processing software.

Commercial applications are envisioned in transportation (foreign object detection, vehicle tracking - assisting the AMBER Alert system for example), medicine (detection, tracking, and identification of fluorospheres), security (malls, nursing homes, etc), homeland defense (base security), and sporting events (tracking a tennis ball for example).



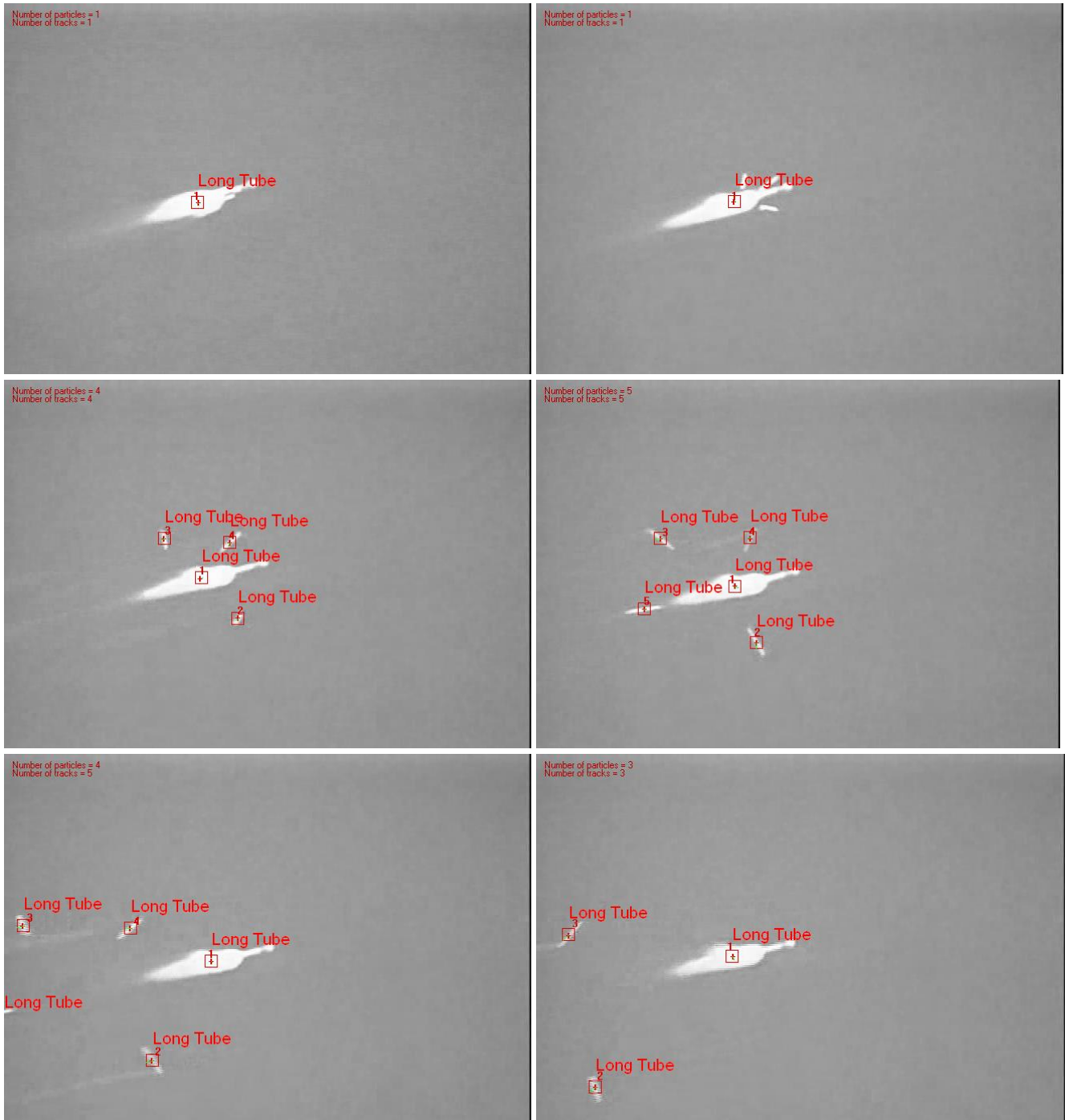
Each station was equipped with a 4Mpixel high-resolution cameras and 200mm zoom optics mounted on a pan-tilt tracking mount, a National Instruments real-time processing architecture to process the acquired imagery into individual object tracks, and a co-located inertial measurement unit (IMU) and GPS to allow for post-processing fusion of the collected data into three-dimensional tracks complete with size and shape information. Software algorithms were developed for detection, tracking, closed-loop track mount control, station alignment, shape and size analysis, multi-sensor data fusion, triangulation, and ground impact point determination. The system was extensively tested on commercial airliners, launched rocket image sequences, tethered balloons, and recreational parachutists. During some scenarios, a co-located GPS on the tracked object was used for data comparison.

The system was designed for these testing scenarios. A follow-on system designed for a more severe launch scenario would require tracking and identifying 50 to 100 objects varying in size from tens of square meters ($>10\text{m}^2$) down to less than a square meter (1m^2) and at ranges out to 70km. These specifications (in particular, ranges out to 70 km) would require additional development effort and advances beyond the current state of the art in imaging (pixel counts), track mount stability, and processing capabilities. Selecting the parachutist field test enabled OPTRA to concentrate our development more on the detection, tracking, and shape identification

algorithms while demonstrating a path to the final application.

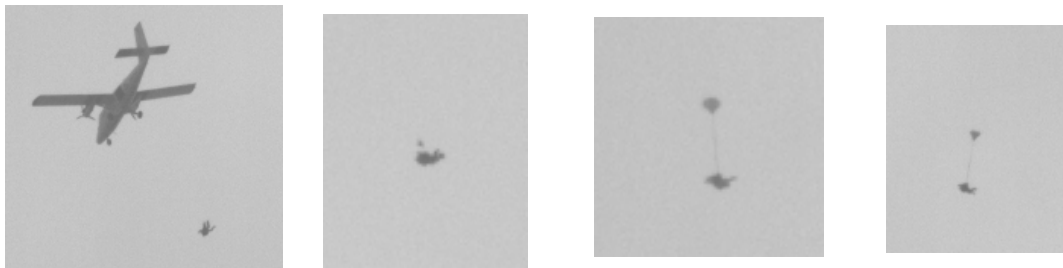
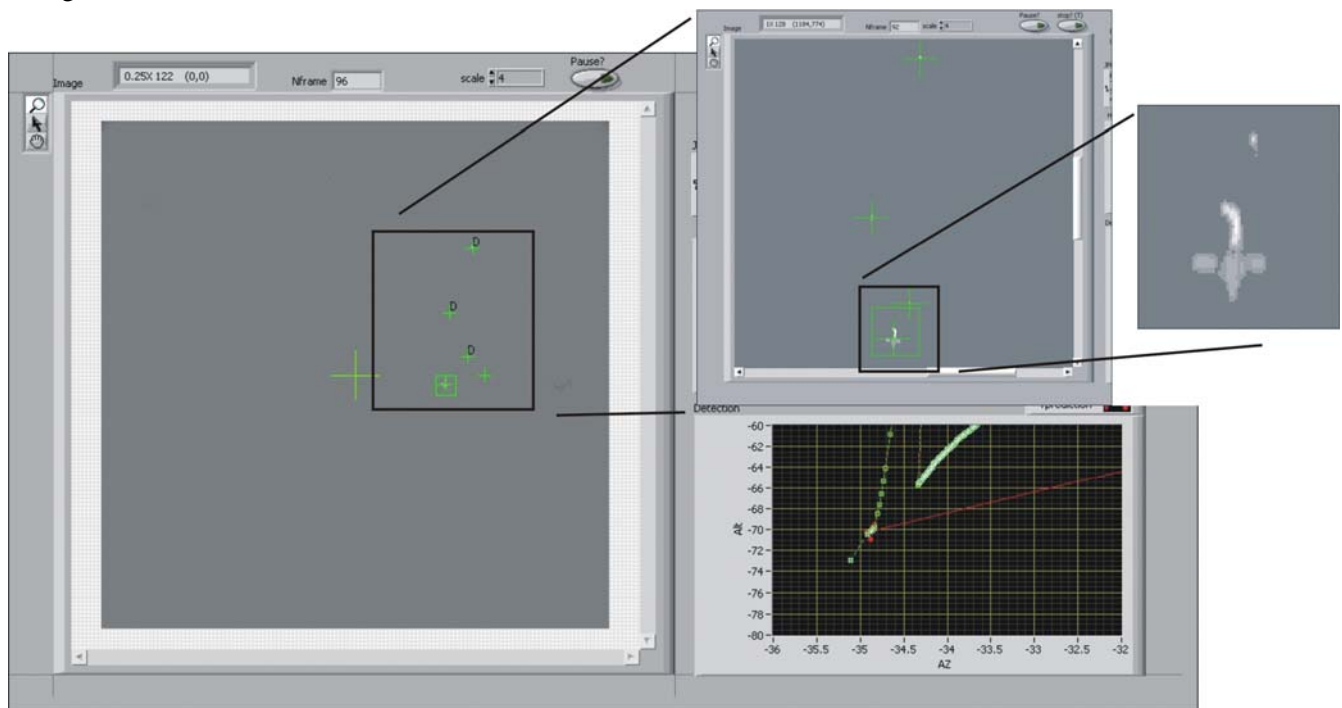
Each sensor is completely standalone, independent of the processing of other sensors. No data needs to be transferred between sensors in real-time. Only one camera is needed for shape and size identification because the object spin allows multiple views of each object. Multiple sensors increases clear viewing of each object and the determination of the three-dimensional ground impact positions during post-processing of each sensor's data streams.

The figures below detail the results of this algorithmic process on a successful booster rocket separation image sequence. An '+' denotes a detection on that object, a 'box' denotes the object selected from primary track (the launch vehicle), the number next to the box is the track file number, and the shape label denotes the shape determinations.



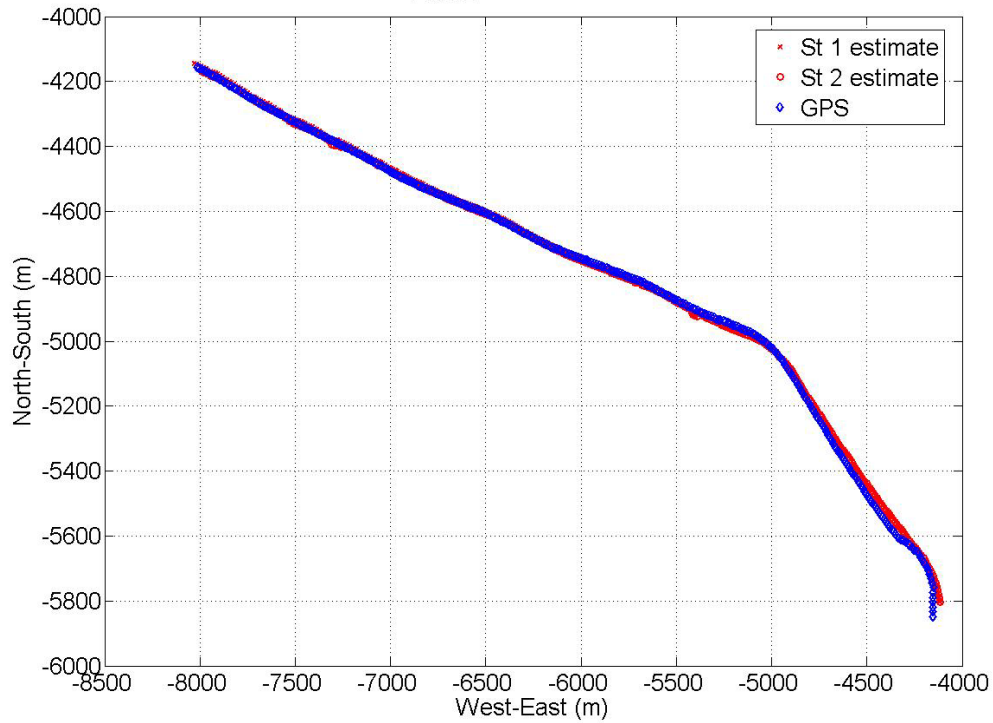
The system currently identify six basic shapes (sphere, disk, cone, thin rectangle, long tube, and cube) with better than 90% accuracy and estimates their size in three dimensions. Within each sensor's processing, this estimate is in pixel units, but once post-processing triangularization is performed and the objects range is known, these estimates are converted to length units. Approximately 75-150 pixels are need on an object in order to achieve greater than 90% identification accuracy.

While observing recreational parachutist operations OPTRA successfully tracked the plane on its ascent to drop altitude (~14 Kft), then detected and tracked parachutists as they exited the aircraft (a simulated debris event) as shown in the figures below. When all three parachutists exited the plane and passed the criteria for a debris event, each is labeled as a piece of debris with a 'D' annotation and the system transitions to the "Debris Track" phase. From this point on, the center of these debris objects would be tracked as they fall to the ground and object angular position and other size and shape attributes are saved on each frame for post-processing triangulation.



The plots below show a comparison between position estimates from sensor data triangulation as compared to an on-board GPS on the aircraft. The data is in reference to the launch point of the aircraft but could also be provided in Lat-Long-Altitude format. Sources of error in this data include GPS errors in the station location measurements (a standard hand-held GPS was used with a +/-10m error), track mount backlash, IMU errors (an inexpensive unit was used), and asynchronism of track measurements between stations. Simple improvements to the IMU and GPS hardware would significantly reduce this error.

Skydive NE data - Oct 31, 2008
Run 2



Skydive NE data - Oct 31, 2008
Run 2

