

Report on
**Personal Dead-Reckoning System
for GPS-denied Outdoor Environments**

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This report documents an outdoor personal locator test performed by firefighters from CAL FIRE



CAL FIRE firefighters set up for a “cover in place” maneuver during the hike on Stone Wall Peak trail. The two firefighters with the red head gear wear our IMU-instrumented Altama boots. This maneuver had absolutely no impact on the tracking performance of our PDR system.

Stone Wall Peak Trail

Tests were conducted outdoors, with the help of firefighters from CAL FIRE. The test area was Stone Wall Peak, a mountainous hiking trail about 3.2 km (2.0 miles) long. The purpose of this test was to assess the performance of the PDR system under entirely GPS-denied conditions. The system used magnetometers and an IMU that was embedded in the heel of army-style boots.

The nominal path, recorded by CAL FIRE firefighters a few weeks ahead of the test (with a handheld GPS unit), is shown as the yellow line overlaid over the Google Earth satellite image of Figure 1. In the actual test two firefighters and one member of our team walked the whole trail with our PDR units. The two firefighters units produced red and green trajectories on our Operator Console Unit (OCU, also called Incident Command Unit). The unit worn by our team member produced a blue trajectory.

All trajectories were plotted over 2-D satellite images from Google Maps. It is important to use the 2-D maps from Google Maps, not maps from Google Earth. This is because Google Earth maps

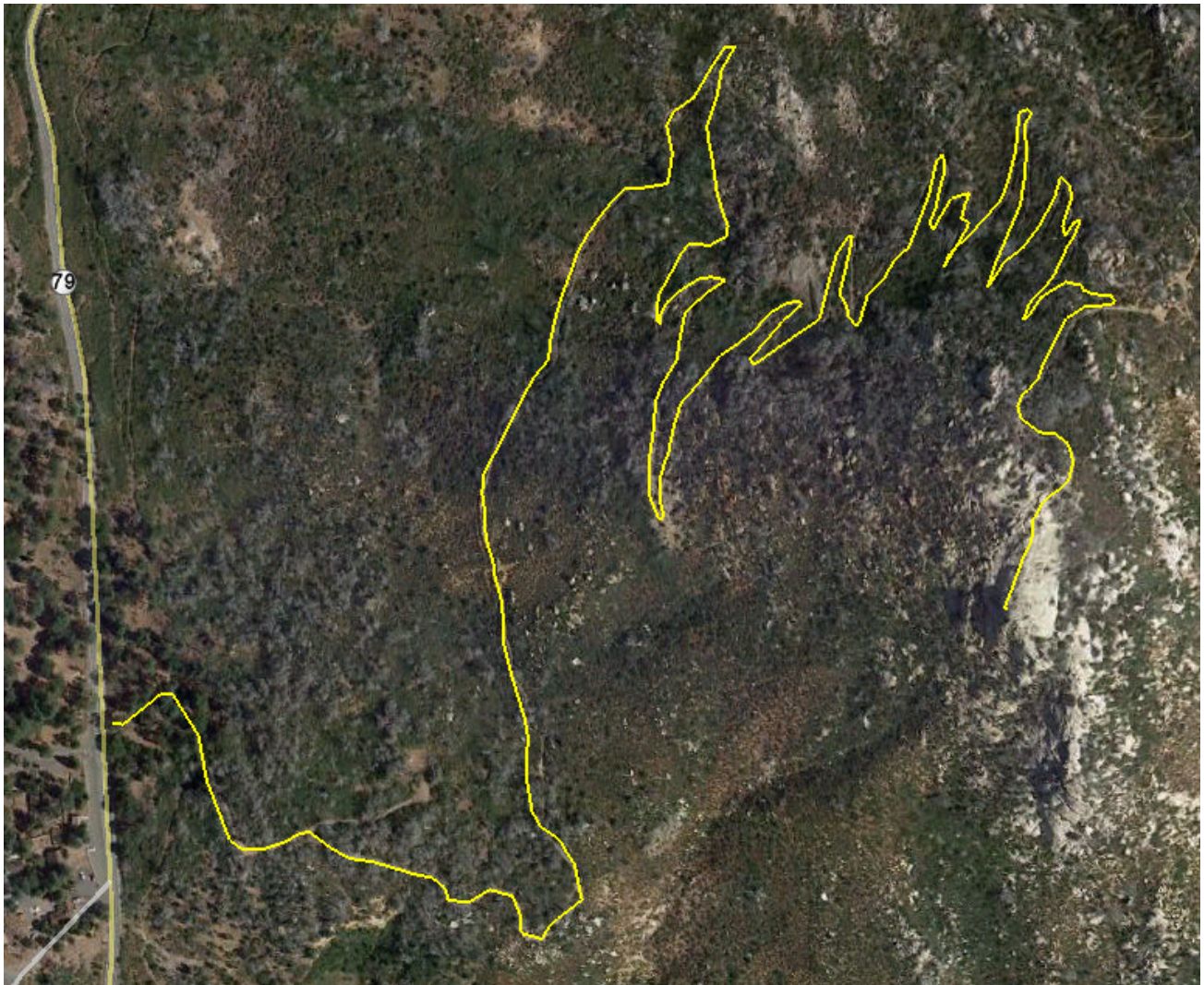


Figure 1: The Stone Wall Peak trail near Julian, California, was the test environment for the outdoor test on Day 3.

have significant distortions when showing rolling or mountainous terrain, whereas maps from Google Maps are distortion-free.

It is apparent from the plots that at no time a position error exceeded ~40 meters, and most of the time position errors were much smaller, well under 20 meters. These are rather remarkable results, given the length, ruggedness, and partially steep inclination of the terrain, as well as the duration of the hike (about 1 hour in each direction). Indeed, for the most part the performance of all three PDR units rivals that of consumer grade GPS units. The duration of the ascent was 68 minutes.

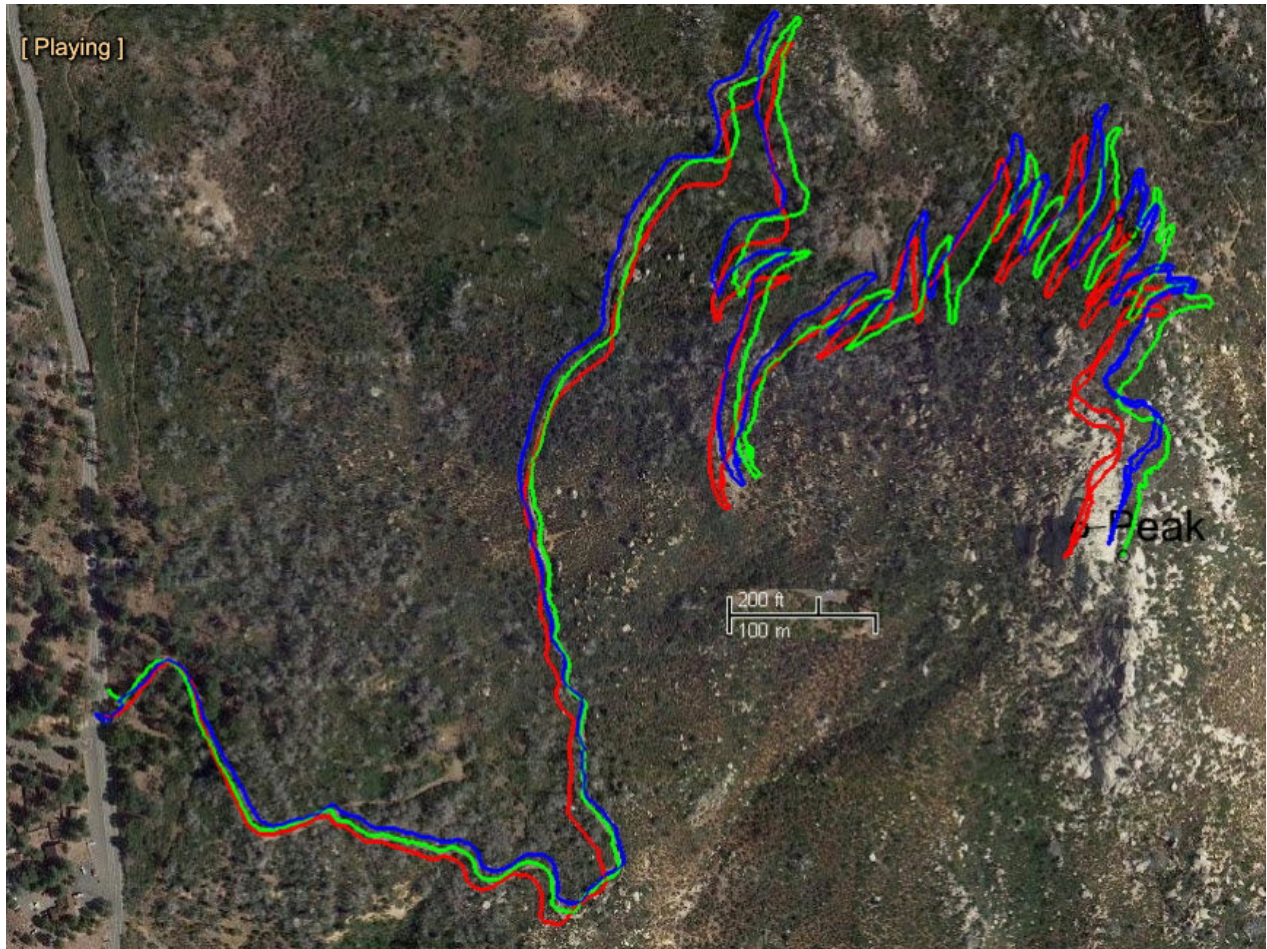
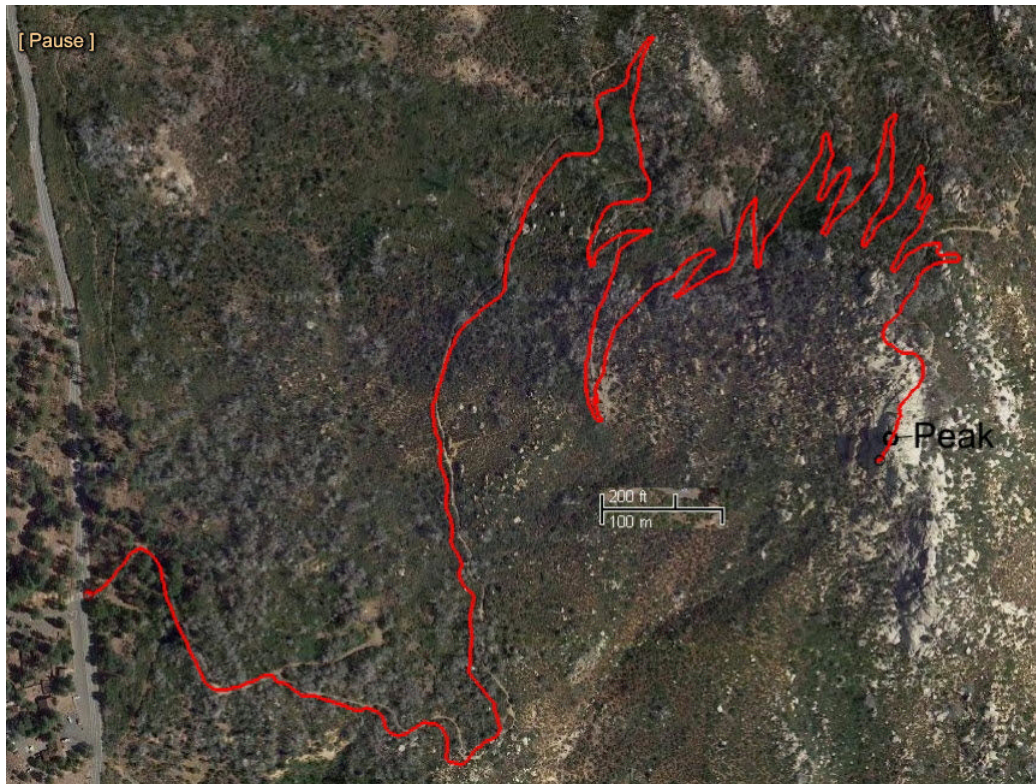
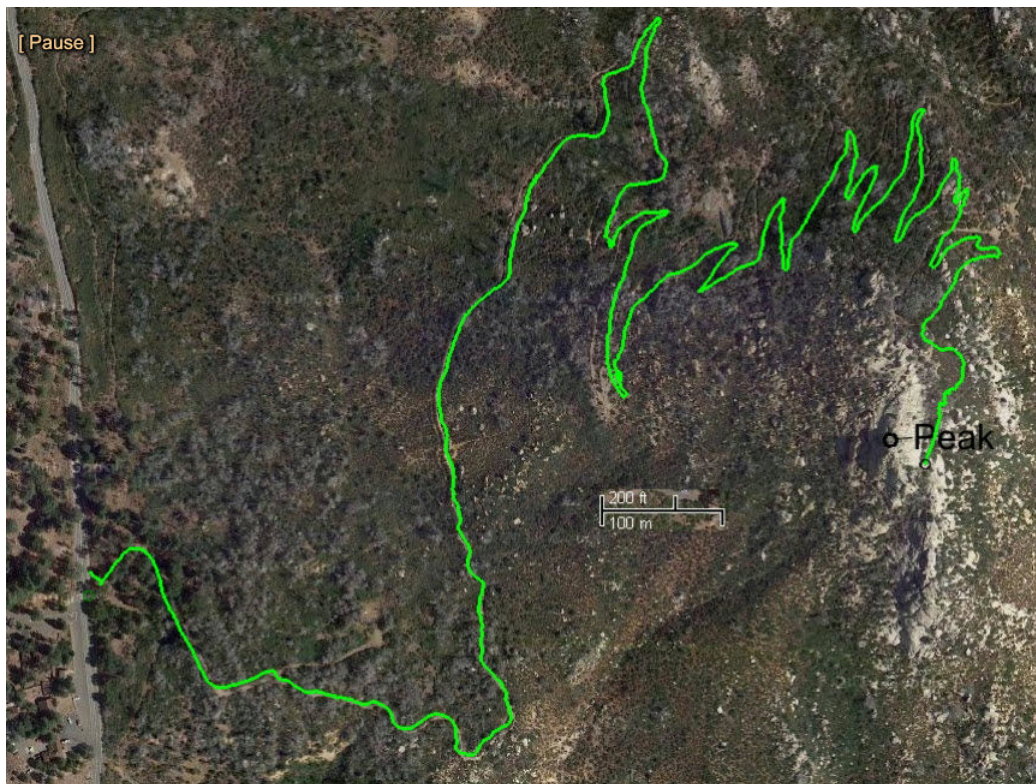


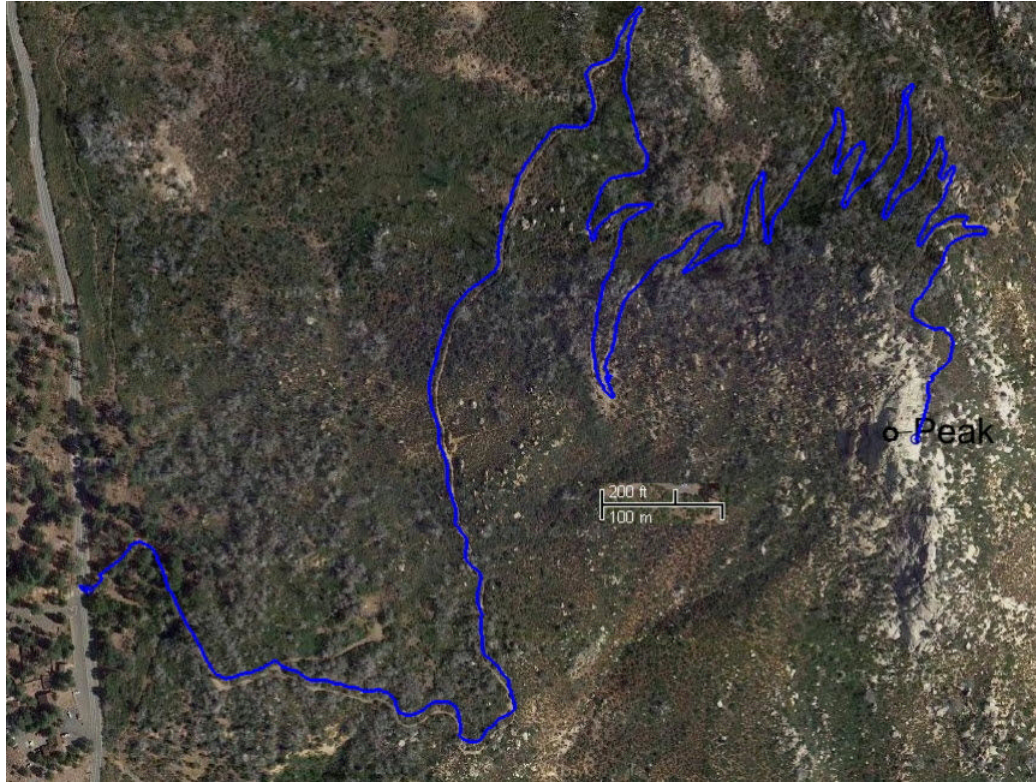
Figure 2: Trajectories as recorded by all three PDR units using IMU and magnetometer only, overlaid over a distortion-free 2-D satellite image from Google Maps. Since the only faintly visible trail is obscured by the three trajectory lines, we provide below three additional plots, one each for each trajectory.



a. Trajectory of the Blue PDR unit



b. Trajectory of the Green PDR unit



c. Trajectory of the Blue PDR unit

Figure 3: In order to avoid occlusion of the only faintly visible hiking trail, we plotted all three trajectories separately.

CONCLUSIONS

Performance outdoors with just the magnetometers and the IMU was extraordinarily good. During a 2-mile, more than hour-long hike up a partially steep mountain trail, none of the three PDR system produced position errors greater than 40 meters.