PALMS Validation Study Summary

Objectives:

1) To determine the sensitivity and specificity of PALMS in detecting personal-vehicle, bus, bicycle, and walking trips and trip modes:
    a. When epoch length changes (shorter epochs can improve location accuracy but may increase frequency of interference)
    b. When the devices begins as a cold or warm start (cold starts can impede GPS signals and trips can be lost while signal detection occurs)
    c. When there are continuous changes in transportation mode or paused changes in transportation mode (pauses often indicate a change in mode)
    d. When trips occur in open areas or urban-canyon areas (urban canyons e.g. high rise buildings can interfere with GPS signals)
    e. When different GPS device models are employed (different models have different accuracy and signal capture time)
    f. When trips end or begin in different building types (buildings can interfere with GPS signals)
    g. When different modes proceed or follow each other (some modes are more distinct so changes are more apparent)
2) To determine the sensitivity and specificity of PALMS in detecting indoor and outdoor location fixes:
    a. When the building has partial or no signal
    b. When the building is a closed or open mall
    c. When walking or stationary within a building
    d. When movement quickly changes from indoor to outdoor repeatedly

Trips were conducted on multiple days at different times of day to account for differences in satellite positions, Further, satellite data were collected on the Qstartz device. Satellite positions in the sky can vary be geographic region and may influence GPS signals.

Note: For individual country/region studies, additional transportation modes or other local conditions may be important to test. PALMS employs user-defined parameters so it is important to know the optimal parameters for your local conditions.

Equipment used in PALMS validation study:

The equipment was carried in a standardized way to reduce error in positioning differences across conditions. Trained raters carried the devices, followed trip protocols for designated trips and completed trip logs to register the trip timings and any unavoidable deviations.

A) 1 Garmin GPS watch worn by the research assistant to establish UTC time in the trip log notes
B) Trip log for each day of data collection including instructions for each trip, maps, and tables for details of each trip to be noted including start/end time etc.
C) A back pack to carry equipment
D) At least 2 boards with GPS devices

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    a. Each board had 6 GPS devices with 3 Qstarz and 3 DG-100 devices set to 5 second, 15 second and 30 second collection epochs

    b. One boardwas a "warm start" board, with each device turned on and having acquired a signal before the start of data collection

    c. The other boards were "cold start" boards, with each device turned on before the start of the specified trip. Raters can collect data on multiple cold start trips during a day of data collection with a separate cold start board for each trip.

E) 1 GT3X accelerometer – set to collect at 1 second intervals

F) 1 GT3X+ accelerometer - set to collect at 30 Hz

G) 1 ActiTrainer with polar strap – set to collect heart rate and activity at 1 sec intervals

Note: For individual country/region, studies a single GPS and accelerometer can be used. If researchers are interested in comparing device models and epochs to inform device settings for a study, the board system allows standardization of device positioning. If you are using the Qstarz GPS make sure satellite information is recorded.

Settings:

We investigated two main settings: urban canyons and open space. Urban canyons e.g. downtown areas can cause GPS interference. For each combination of trips, we required 4 examples. Thus eight locations (four downtown and four open) were selected

We identified eight different "travel corridors" in San Diego County. A travel corridor was defined as a segment of a street where it is possible to travel by all modes of transportation under study. In downtown areas where it is impossible to travel in both directions along a oneway street, two adjacent streets were used and defined as the travel corridor.

Rationale: Conducting trips along a single travel corridor allows for collection of different transportation modes while keeping the built environment constant thus ensuring that any differences found during data collection were due to the devices specifications and not built environment differences.

Design: *Transportation Trips and mode detection:*

Trips comprised two different transportation modes with and without a short 2-minute pause between them. The end of the trip pair was defined by a longer 4 minute pause. All combinations of vehicle, bus, bicycle, and walk trips were collected along each travel corridor. Continuous trips were only included where appropriate for the mode, e.g, Car to bus naturally involves a short walk to the bus stop or waiting for the bus. However, raters were instructed to immediately board the correct bus when it arrived at the stop regardless of the prescribed pause time. This allowed for the capture of some continuous "to-bus" trips without extensively prolonging the data collection period or asking for unsafe maneuvers through heavy traffic. Where appropriate, trips ended in outdoor or indoor locations as the signal interference from a building can also serve as an indicator of a trip end.

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The distance for each vehicle, bus, or bicycle trip measured between 800 and 1500 meters and each walk trips measured 800 meters.

Warm Start Trips

Trip	Downtown Paused	Downtown Continuous	Open Space Paused	Open Space Continuous
Walk	26	22	26	25
Car	30	25	30	30
Bus	26	13	26	17
Bicycle	26	22	26	22

Total Trips: 392

Cold Start Trips (planned)

Trip	Downtown Paused	Downtown Continuous	Open Space Paused	Open Space Continuous
Walk	13	9	13	9
Car	12	8	12	8
Bus	13	13	13	13
Bicycle	13	9	13	9

Total Trips: 180

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Warm Start Tours:

Activity Description	Downtown Paused	Downtown Continuous	Continuous Paused	Continuous Continuous
Walk to Car	4	4	3	3
Walk to Car, end in garage	1	1	1	1
Walk to Car, begin in building	0	0	1	2
Walk to Bus	4	0	4	0
Walk to Bicycle	4	4	4	4
Car to Walk	4	4	3	4
Car to Walk, begin in garage	1	1	1	1
Car to Walk, end in building	0	0	1	1
Car to Bus	4	0	4	2
Car to Bus, begin in a garage	1	0	1	0
Car to Bicycle	4	4	4	4
Car to Bicycle, begin in a garage	1	1	1	1
Bus to Walk	4	3	3	5
Bus to Walk, end in building	0	1	1	0
Bus to Car	4	4	4	5
Bus to Car, end in a garage	1	1	1	1
Bus to Bicycle	4	4	4	4
Bicycle to Walk	4	4	4	4
Bicycle to Car	4	4	4	4
Bicycle to Car, end in a garage	1	1	1	1
Bicycle to Bus	4	0	4	0

Total Tours: 196

Cold Start Tours (planned):

Activity Description	Downtown Paused	Downtown Continuous	Open Space Paused	Open Space Continuous
Walk to Car	4	4	4	3
Walk to Car, end in garage	1	1	1	1
Walk to Car, begin in building	0	0	0	1
Walk to Bus	4	0	4	0
Walk to Bicycle	4	4	4	4
Car to Walk	4	4	4	3
Car to Walk, end in building	0	0	0	1
Car to Bus	4	0	4	0
Car to Bicycle	4	4	4	4
Bus to Walk	4	3	4	4
Bus to Walk, end in building	0	1	0	0
Bus to Car	4	4	4	4
Bus to Car, end in a garage	1	1	1	1
Bus to Bicycle	4	4	4	4
Bicycle to Walk	4	4	4	4
Bicycle to Car	4	4	4	4
Bicycle to Car, end in a garage	1	1	1	1
Bicycle to Bus	4	0	4	0

Total Tours: 180

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Building Trips:

Raters completed "building trips" where "trip" was defined as a stationary or walking period within a building and repeated threshold crossings into and out from buildings. These trips occurred at open space and urban canyon locations within closed malls, open malls, partial signal and no signal buildings. Closed mall and open mall trips occurred in both downtown and open space locations while partial and no-signal building trips were collected regardless of location.

Total trips: 64

Closed Mall and Open Mall Building Trips

Activity Description	Closed Mall		Open Mall	
	Downtown	Open Space	Downtown	Open Space
Walking Inside	4	4	0	0
Stationary Inside	4	4	4	4
Repeated Threshold Crossing (5 times)	4	4	4	4

Partial Signal and No Signal Building Trips

Activity Description	Partial Building	No Signal Building
Walking Inside	4	4
Walk to outside	4	4
Stationary	4	4

Annotated Data Set:

A trip log was collected for all activities during data collection by raters in the field. The rater used a GPS watch to note times for different activities during data collection. Raters noted the start of trips, pauses, movement transitions and environment transitions for the annotated data set. Movement transitions were defined as changes in modes of transportation and changes from stationary to moving. Environment transitions were defined as entering and exiting building and parking garages. Raters noted start times for changes in movement in the trip log. Therefore, starts of trips such as a bus trip began when the bus started to move not when the rater entered the bus. Raters also noted the start time for any cold start devices that were turned on before the start of a specified trip pair. Also noted was whether there was a cloudy or clear sky, which can affect the GPS signal quality.