# Performance of a Backpack GPS in a Tropical Rain Forest

*David S. Wilkie*
Department of Anthropology, University of Utah, Salt Lake city, UT 84111

ABSTRACT: To assess the practicality of NAVSTAR GPS location determination within an isolated forest region, a battery powered, solar recharged, backpack mounted GPS receiver was assembled and tested over a 6 month period within the Ituri rain forest of northeastern Zaire. A Magnavox 4400 GPS receiver was attached to a tubular aluminum backpack frame, with a two-foot detachable antenna. The system was powered by a 12v gel cell, recharged with an ARCO G100 solar panel. Gel cells were fully recharged after 18 hours and provided 3 hours of power to the GPS receiver. Three-dimensional geographic locations were readily obtained within 20 minutes in forest openings > 0.125 ha, where angle to horizon did not exceed 50°, and canopy closure was less than 20 percent. Overall, the backpack GPS proved to be an effective means of obtaining accurate location data, even in an inaccessible rain forest region.

## INTRODUCTION

THE NAVSTAR satellite Global Positioning System (GPS) provides for accurate geographic positioning around the globe. This is of particular importance in inaccessible, highly heterogenous areas, where large-scale topographic maps are unavailable, and where suitable features for ground based navigation by triangulation are absent. Although mapping and remote sensing applications in isolated regions, such as tropical rain forests, would benefit greatly from GPS technology, present systems are primarily designed for shipboard or terrestrial vehicle use where power supply and line of sight access to three or four satellites are not limiting factors.

To assess the practicality of GPS location determination within an isolated region, a battery powered, solar recharged, backpack mounted GPS system was assembled and tested over a 6-month period within the Ituri rain forest of northeastern Zaire.

The Ituri tropical moist forest lies between 0 and 3 degrees North latitude and 27 and 30 degrees East longitude and covers an area of some 6.3 milliion ha (Figure 1). The region is still predominantly climax forest composed of hardwood legumes of the family Caesalpineaceae (Wilkie, 1987). Climax forest is interpersed with seral communities of various ages that developed in gaps from old tree falls and lightning strikes, and where shifting cultivators abandoned their fields (Wilkie, 1988; Wilkie and Finn, 1988). High species diversity within each community and the mosaic structure of mature and seral patches makes for an extremely heterogenous landscape. Three roads built in the early 1940s traverse the Ituri; however, most of the forest is only accessible on foot. Topographic maps larger than 1:1,000,000 in scale, such as the Defense Mapping Agency's air-navigation charts, are unavailable, and suitable features for ground based navigation/positioning by triangulation are absent.

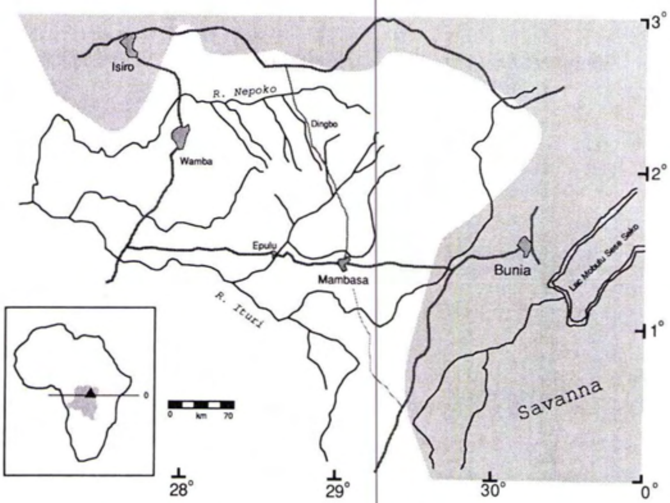


FIG. 1. The Ituri rain forest of northeastern Zaire.

Accurately locating and surveying unique land-cover types within inaccessible and poorly mapped areas of the Ituri forest is thus extremely difficult or impossible. Assembly of a battery powered, solar recharged, backpack GPS offered a solution to these geographic positioning problems.

## THE SATELLITE GLOBAL POSITIONING SYSTEM

The Magnavox 4400 receiver accesses the global positioning system (GPS) developed by the U.S. government. Once all 18 NAVSTAR (Navigation System with Time And Ranging) satellites are in orbit, the system will provide accurate navigation and geographic location 24 hours a day any where on the globe (Anon, 1986). Satellite GPS will replace the older Omega, Loran-C, and Transit navigation systems (Rodgers, 1983; West, 1988).

NAVSTAR satellites circle the earth in 20,200-km circular orbits with a 12-hour period (Heuerman and Senus, 1983). The orbital geometry of six 55° inclined planes with three satellites in each plane will enable reception of direct line-of-sight navigation signals from at least four satellites at any point at or near the Earth's surface at all times. Six functional NAVSTAR satellites presently provide 10 hours of two- and 6 hours of three-dimensional position coverage per day around the globe (Anon, 1986).

Each satellite transmits a coarse/acquisition navigation signal (1575.42 MHz) that provides civilian users with geo-positioning to 15 m RMS. A more precise signal is restricted for military use. Simultaneous monitoring of three satellites gives two-dimensional (latitude and longitude) position when altitude is known using a hand-held or optional internal barometric altimeter. Four satellites provide complete three-dimensional positioning. Position determination is possible with only two satellites if altitude is known or provided by an optional onboard altimeter, and an external cesium 5.119155 MHz frequency standard is connected to determine clock bias.

Location of the user is determined from known satellite position, transmitted by NAVSTAR, and time-of-arrival estimates of the satellite's navigation signal. Additional information on the clock bias of the satellite time-base allows for correction of the initial satellite-to-receiver pseudo-range calculations. The two-

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or three-demensional position is computed using Kalman Filter navigation software. The velocity of the user can also be determined from Doppler measures of the navigational signal carrier frequency (Anon, 1986).

## ASSEMBLING A PORTABLE GPS RECEIVER

A Magnavox 4400 GPS receiver, primarily designed for shipboard or land vehicle applications (Stansell, 1987), was adapted for the roadless terrain of the Ituri forest. This was accomplished by attaching the unit to a tubular aluminum backpack frame equipped with a two-foot detachable antenna. The system, which draws 20 watts, was powered by a 12v gel cell (DRYIT 2000, 6 amp/hr) that was recharged with an ARCO G100 (5 watts, 14.5 volts) solar panel. The complete system, frame, receiver, antenna, pre-amp, cables, two gel cells, and solar panel weighed 16kg (Figure 2). As a final detail, a nylon backpack cover was used to protect the coaxial cables from damage.

## RESULTS

The Ituri constituted a harsh test of the systems capabilities as humidity averages 70 to 90 percent, torrential rains are frequent, and the choice of power source is limited to solar energy. In addition, average area open for line-of-sight reception of satellite signals is generally small and often partially obstructed by a leafy canopy.

The system was tested between February and July, 1988. A four-satellite constellation was available (above the horizon) 6 hours per day. Satellite rise and set times advanced approximately 4 minutes per day and varied from 1740 to 2340 in early February to 0720 to 1320 in early July. These times are obtained by querying the GPS receiver. Time from power-up to acquisition of one satellite varied according to the size of the canopy opening, and averaged 11.5 minutes ($n = 114$, $t_{min} = 7$ minutes, $t_{max} = 79$ minutes). Positioning with three or four satellites was usually possible within 20 minutes, with stabilization of location values 4 to 10 minutes after onset of navigation.

A three- or four-satellite constellation was readily obtained in villages, fields, and plantations (open area > 0.125 ha) where angle to horizon rarely exceeded 30°. Although a stable position was usually obtained within 25 minutes in open canopy areas, much longer periods were required in small forest clearings where angle to horizon often exceeded 40° and canopy closure reached 30 percent. Forest gaps where canopy closure exceeded 30 percent and angle to horizon averaged more than 50° generally precluded acquisition of a three- or four-satellite constellation. Satellites higher than 70° above the horizon do not provide useful data for position determination.

Once a geographic position was obtained, the GPS was easily transported from one site to another, allowing multiple location determination. Satellites were often lost when passing through closed vegetation zones but were quickly reacquired when gap size expanded again in open vegetation areas. A new geographic position was generally obtained within 5 minutes of relocation in open gap areas.

Eighteen cloudless hours of equatorial sun were required to fully charge the 12v Gel cell, which could then provide 3 hours of GPS operation. Although this was ample for open canopy areas, it was limiting in small gap locations. In small gaps, extended periods of time were needed to obtain three or four satellites that were sufficiently high above the horizon and at a suitable azimuth to penetrate the spaces in the canopy. Prior knowledge of satellite trajectories (azimuths and angle above the horizon) would enhance the users ability to select areas and times for GPS data collection such as to minimize satellite acquisition time and, concommitantly, battery drain.

FIG. 2. A backpack, battery powered, solar recharged GPS receiver.

## CONCLUSIONS

The backpack GPS performed well under demanding conditions and was able to obtain three-dimensional positions in inaccessible areas often moderately enclosed by vegetation.

The field test has demonstrated that the use of satellite global positioning technology is a practical means of obtaining accurate geographic location data in inaccessible, poorly mapped regions of the world. A backpack GPS should therefore be of considerable utility to a wide variety of researchers in remote sensing, archaeology, geography, and ecology.

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