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WHITE PAPER

IMPACTS OF SATELLITE-BASED POSITIONING SYSTEMS ON AMATEUR RADIO DIRECTION FINDING

Charles E. Scharlau - NZØI

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INTRODUCTION

The purpose of this white paper is to describe the types of navigation assistance that satellite-based positioning systems (GPS, GLONASS, etc.) can offer to competitors in radio-orienteering activities. This paper provides background on the capabilities of positioning systems as they exist today, and examines their impact on the sport of Amateur Radio Direction Finding (ARDF). The focus is on the capabilities of devices that can be readily obtained or constructed today.

Only devices providing NO map display are considered in this paper since devices capable of displaying maps are currently banned from international competitions held in some IARU regions, and because "eyes-free" navigation assistance can be more convenient, portable, and effective than if a display were utilized. This paper concludes by examining the likely impacts as satellite-based positioning is incorporated into the sport of ARDF.

This paper is NOT a position paper on ARDF rules. It does not advocate for or against the inclusion of satellite-based positioning assistance in ARDF. It does, however, examine the likely impact of such assistance on the concept of fair play in the sport, and suggests an approach to maintain fairness where GPS usage is concerned.

The author takes full responsibility for the paper's content. Accordingly, this document does NOT represent official American Radio Relay League (ARRL) policy or proposals for policy change. The purpose is to stimulate responsible discussion within the ARDF community regarding the best ways to address the issues introduced by satellite-based positioning systems.

I invite interested parties to comment on this paper by email to nz0i@openardf.org.

CONTENTS

I. BACKGROUND

Fundamentally, all location information is the same. Whether it is derived using map and compass or received as a latitude and longitude from a satellite navigation (satnav) instrument: a location is simply a position on Earth.

For the remainder of this document, satellite navigation systems, and receivers or modules used to obtain information from those systems, will be referred to using the term Global Positioning System or "GPS". This is done for brevity and convenience. The reader should be aware that multiple satellite navigation systems currently exist or are in the planning or development stages, and all of them function in much the same manner.

Latitude and longitude are reference frame coordinates that specify a particular point on Earth's surface relative to a defined origin (latitude=0, longitude=0). The reference frame most often used for GPS is taken from the World Gedetic System WGS84 which places the origin at a location along the equator located off the west coast of Africa in the Atlantic Ocean.

Navigation sports like ARDF typically use a map that is referenced to an origin defined by the Start. Competitors gather at or near the Start to receive competition maps on which the Start location is clearly marked. Thereby competitors are provided with a single, original point on the map where they know precisely their location. For much of the remainder of a competition, ARDF participants must use their map-reading skills and their compass in order to maintain or re-establish knowledge of their map position. The accuracy of their derived position determines how well they can plan efficient routes, plot accurate bearings, and successfully navigate to all their assigned transmitters and eventually arrive at the Finish.

Clearly, numerical latitude and longitude data indicating proximity to a point in the Atlantic Ocean is of little use to those carrying just a paper map and magnetic compass. A position that is referenced to the paper map is what is needed.

If, however, in addition to a map and compass, a microprocessor capable of processing latitude and longitude is added, then GPS location data become much more useful. Utilizing a single known position on the map (the Start), latitude and longitude data can be referenced to the paper map. Establishing the Start as a reference point requires only the push of a button. The microprocessor, then, can process the GPS positions to provide

locations referenced to the Start in a human-readable format, such as distance in meters and magnetic bearing direction.

Knowing one's distance and direction from the Start can be of assistance when ARDF competitors lose track of their position on the map. But GPS positions can be much more useful than that. Most GPS modules can provide accurate location updates once every second or faster. Those positions can be recorded in computer memory as waypoints and tracks, or incorporated into bearings, and utilized to provide audio-based navigation aids.

ARDF rules makers and administrators need to be aware of the capabilities of satellite-based positioning devices in order to understand their potential impact to the sport. The remainder of this paper explores GPS's capabilities and potential impacts to ARDF, and examines its impact to fairness in the sport.

II. GPS NAVIGATION CAPABILITIES

Most of us are familiar with the use of GPS to determine our current location and display it on a map. Automobile navigation devices not only display the car's position imposed on a street map, they can also determine an optimum route and provide turn-by-turn navigation instructions to the driver. GPS device memory and processing capabilities are sufficiently powerful that they can do all of that autonomously, without communicating with a networked server.

Currently, some ARDF rules disallow GPS devices having the capability of displaying a map. And turn-by-turn directions are not very helpful when there are no roads, and no known transmitter location to specify as a destination. Regardless, some very remarkable navigation assistance can be provided to ARDF competitors despite the challenges imposed by the rules and the lack of known predetermined destinations.

A single accurate GPS position recorded at the Start (or any other easily-referenced map feature) is all that is required to translate between the GPS and paper-map coordinate systems. A single button press can inform the processor to record and utilize the Start location. After that is accomplished, each new position update can be referenced to the Start. Many of the navigation features of interest to ARDF competitors utilize numerous location data points taken over the course of a contest. A typical GPS device can deliver 3600 or more accurate positions during each hour of a competition, allowing a complete track of a competitor's path to be recorded.

Satellite constellation geometries, overhead vegetation coverage, and atmospheric conditions can all impact the accuracy of the position information provided by GPS. In practice it is not unusual for positions to be accurate to within 10 meters consistently and reliably. Basic position filtering implemented in software (e.g., Kalman filter) can improve matters by removing some of the random position variations. GPS is routinely

used to provide useful data for navigating roads at highway speeds. Accuracy is generally better in open to moderately-wooded areas where GPS signal reflections from buildings and signage is less of an issue. So the accuracy of each GPS-provided location data point is roughly comparable to what a competent orienteer might achieve in a competition situation - sometimes better, and sometimes worse. But, unlike orienteers, no more than a few seconds are likely to pass during which the GPS device does not provide a highly accurate position fix.

GPS location data can be more useful than simply providing a competitor with their current position on the map. Numerical location data can be readily used to calculate information supporting navigation features useful in ARDF. Great-circle trigonometry formulae, widely available on the Internet, allow tinkerers to create their own ARDF-optimized GPS devices using basic micro-controllers and miniature GPS modules. World Magnetic Model software is freely available on the Internet, allowing magnetic declination to be calculated for any point on Earth - making it simple for devices to provide directional guidance in degrees magnetic, compatible with orienteering maps.

A sample of just some of the readily-accomplished ARDF navigation features includes:

- A competitor's distance and direction from the Start.
- A competitor's track since leaving the Start along the path to the current location.
- Distance traveled along the track or any segment of the track.
- Particular waypoints set by the user, such as visited transmitter locations, as well as distance and direction to (or from) them.
- The exclusion zones around the Start and any found transmitters, and notifications when the exclusion zones' boundaries have been crossed.
- Course (direction of travel) information can be calculated indicating an individual's approximate direction of movement. Course data can be substituted for compass bearing direction to provide directional features.

If directional information from an electronic compass device is supplied to the microprocessor (or approximated using course calculations) along with location data then more ARDF features become practical:

- Recorded bearings with the precise locations at which they were taken.
- Calculated locations of where recorded bearings intersect, and estimated locations of transmitters based on those intersections.

- Elevation data is often available in addition to the latitude and longitude. Elevation can be used to weight bearings in order to enhance transmitter-location estimates.

- Distance and compass direction to the estimated transmitter locations – even an arrow (or audio indication) guiding the way.

- Straight-path navigation guidance with cross-track error in any chosen compass direction.

More navigation features are possible. How many more depends on one's imagination, know-how, and available processing power.

A graphical display would be effective for presenting the above information. But audio tones or synthesized voice played in one's headphones can be just as helpful while allowing one's eyes to remain on the trail ahead. None of the features listed above requires a digital map. All of the listed features are feasible using commonly-available technology and basic programming skills.

III. THE UNIQUE NATURE OF SATNAV SYSTEMS

There are several ways that satellite-based global positioning systems fundamentally differ from all other navigation technologies available to ARDF competitors.

As discussed in the previous sections, satellite-based navigation systems provide location data to those carrying GPS receivers. Location data is uniquely helpful in navigation sports, and supports navigation assistance features that cannot be accomplished with anything but location data. Those features, implemented correctly, can reduce the need to rely on orienteering skills traditionally required of ARDF competitors.

No other technology provides accurate and consistent location data without any effort on the part of a competitor. Dead reckoning systems accumulate error over time and distance, and thus require periodic alignment to a new fix position derived and entered by the competitor using the system. Satellite-based navigation systems are unique in their ability to operate accurately without any required user intervention or input.

Traditionally, ARDF competitors have not been allowed to receive navigation assistance from man-made signals coming from outside the competition boundaries. It would be considered unfair, for example, for outside observers to radio their bearing measurements to select competitors on the course. It has been understood that ARDF competitors are expected to derive their navigation information exclusively from the official course map, magnetic compass readings, and the signals emanating from the competition transmitters.

But satellite-based navigation receivers utilize radio signals received from Earth-orbiting satellites located far beyond the course boundaries. Such receivers make no use of the course map, local geomagnetic field direction, or the competition transmitters' radio emissions. GPS receivers provide accurate, reliable, and voluminous location information beyond the capabilities of any human. They accomplish those feats by the efforts of teams of engineers and technicians unassociated with the ARDF competition. In all these respects, satellite-based navigation systems are uniquely distinguished from all other forms of assistance available to ARDF competitors.

There is no evident logic to arguments suggesting that regulating the use of GPS in a navigation sport should require that other technologies unrelated to it be likewise regulated. No restrictions have been placed on the sophistication of ARDF competitors' instruments that derive useful data from any of the traditional field-of-play sources. Commercial or "homebrew" instruments that digitize, filter, or enhance the data supplied by compasses or receivers have always been deemed permissible technologies in ARDF. Restrictions placed on the use of GPS should not logically constitute a precedent that should apply to unrelated technologies.

The unique characteristics of satellite-based navigation systems do not imply that their use must be regulated in or banned from navigation sports. But that uniqueness does clearly illustrate that if GPS is regulated, such regulation need not constitute a "slippery slope" that would affect other technological advances in ARDF sport equipment. Rules wording that specifically sites "automatically-generated location data" or "navigation assistance derived from signals of human origin from outside the competition boundary" would surgically address satellite-based navigation technology without impacting other technologies.

IV. CURRENT ARDF SATNAV CAPABILITIES

Some have made the argument that their GPS equipment doesn't work all that well for ARDF and therefore doesn't provide sufficient competitive advantage to justify its regulation. Such arguments seem misguided for several reasons.

All the navigation features discussed thus far in this writing are within the capabilities of many hobby tinkerers to implement. Many of the features are found in commercially-available GPS navigation receivers where they can be observed to work effectively. And it seems self-evident that those features would provide significant advantage to those who use them.

The GPS features discussed should be considered to be generally available and to work well. Meanwhile, there are several possible explanations for why a particular device, especially a device manufactured by a "basement builder", doesn't provide high performance:

1. Although effective ARDF-optimized GPS devices are within the capabilities of many hobbyists, the necessary software is not trivial to develop, and might be beyond the capabilities of some manufacturers.

2. Some device suppliers might intentionally degrade the performance of the equipment they sell in order to prevent ARDF competitors (especially those who might compete against them) from obtaining the full benefits of the technology.

3. Component tolerances and subtle defects can lead to differences in performance from unit to unit. Many devices sold by small-scale manufacturers lack performance specifications that would allow customers to determine if their particular unit is defective.

Beyond the current situation for devices being used today, technology is advancing quickly. What is challenging today is likely to become trivial in the not-too-distant future. Rules governing ARDF should be forward looking to take advantage of GPS's potential to help the sport, and to prevent any potential harm. Thus, the performance of today's equipment should not be weighted heavily in rules considerations.

V. CONCLUSION

From their inception ARDF competitions have been about using directional antennas, and signals coming from transmitters on the course, to supplement map and compass for navigation. Satellite-based systems deviate from that tradition by utilizing man-made signals originating from far outside the competition boundary, making GPS navigation a unique departure from ARDF traditions.

Departing from traditions can be beneficial. The introduction of GPS into a navigation sport need not represent a threat: it can be an opportunity to breathe new life into ARDF. But given its capabilities, it seems very likely that GPS would readily take the sport in a profoundly new direction: away from a reliance on personal navigation skills, and toward reliance on external navigational assistance.

Less reliance on personal navigation skills can be considered bad, or good, depending on one's vision for ARDF's future. For example, GPS should reduce frustration for beginners and for those with undeveloped map and compass skills. That could help increase the overall number of ARDF participants. But the sport itself would evolve to have fundamental differences from how it is played today.

Location is central to navigation sports. Location is at the heart of what ARDF competitors use to be successful in the sport. And location is precisely what GPS devices provide effortlessly with superhuman accuracy and speed. Regardless one's vision for ARDF's future, it must be acknowledged that few will want to participate in an unfair

sport. If those using GPS are allowed to compete directly against those lacking that assistance, the sport will not be fair. If that day has not yet arrived, it will arrive soon.

The unique characteristics of satellite-based navigation systems allow effective rules to be readily crafted to separate competitors using GPS from those who do not. It would be preferable to implement such rules before GPS usage, and unfairness to those who do not use it, become endemic to ARDF. Alternatively, rules should clearly state that GPS usage is encouraged for all navigational purposes, in order to hasten the day when all ARDF competitors utilize GPS technology.