Global Positioning System (GPS)
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Basic GPS Design

- GPS (DoD) with 24 active satellites, Glonass (Russian Federation) with only nine active satellites, European Galileo (planning stage)
- GPS: Three segments - Space, Control, and User

  Space Segment: 24 satellites + 4 spares in 12 hour, 20,100 km, 55° orbits, four satellites in each of the six orbital planes

  Control Segment: Ground stations adjust satellite clocks, provide orbital parameters (almanac, ephemeris) for each satellite

  User Segment: GPS receivers provide navigational and time information to users

Operating Modes

- Precise Positioning System (PPS) - US and allied military, authorized government agencies - 22 m horizontal, 27.7 m vertical, 100 ns accuracy (95% of time). Resistent to jamming
- Standard Positioning System (SPS) - civilian use - 100 m horizontal, 156 m vertical, 340 ns accuracy with S/A, improved to PPS values after May 1 2000

Operating Modes (cont.)

- Differential Carrier Phase for Surveying With Postprocessing - at least two receivers - sub cm accuracy
- Differential GPS (DGPS) - ground signal required - 1 to 5 m horizontal accuracy
- Wide Area Augmentation System (WAAS) - as of February 2002 implemented only in US with 25 ground stations and 2 geosynchronous satellites. Accuracy - 7 m vertical/horizontal

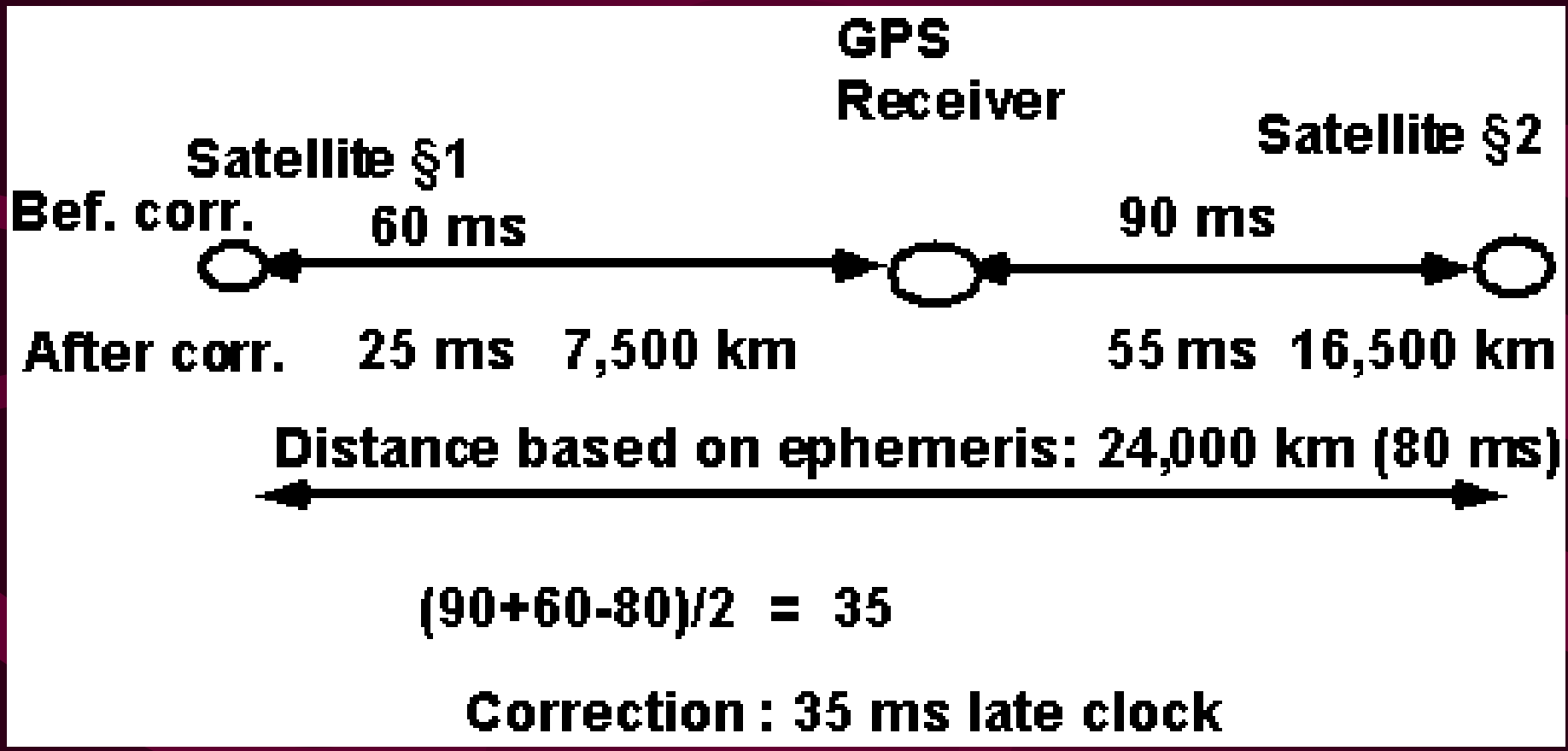
Determining Position on the Globe

- Almanac and ephemeris information, same frequencies but different codes used by each satellite - 1.2 and 1.5 GHz (20 - 25 cm)
- Timing information: Satellite ID and time based on satellite clocks
- Cesium/rubidium clocks - 1 sec in 300 years
- Triangulation by adjusting receiver clock: 1 μs = 300 meters, final precision ±100 ns

Simplified Example of Linear "Triangulation"

- Example: Distance between 2 satellites (from ephemeris information): 24,000 km = 80 ms (c = 300,000 km/sec)
- Time measured to Satellite #1 - 60 ms
- Time measured to Satellite #2 - 90 ms
- Conclusion: local clock in the GPS receiver is late by (90+60-80)/2= 35 ms
- Corrected time to Satellite #1: 60-35 = 25 ms or 7,500 km
- Corrected time to Satellite #2: 90-35 = 55 ms or 16,500 km
- 4 satellites required for 3D triangulation

Simplified Example of Linear "Triangulation"



Sources of Error

- Code noise, receiver noise, satellite clock - 1 m each
- Ephemeris data error, troposphere delay - 1 m each
- Unmodeled ionosphere delay - 10 m , multipath - 1 m
- Satellite constellation geometry - 10 m
- S/A (RIP) reduced horizontal accuracy from 22 to 100 m (95% of time). S/A was introduced in 1980 and discontinued at midnight on May 1, 2000 by order of president Bill Clinton
- Human and software errors can make GPS useless

GPS and Relativity Theory

- Special Relativity (SR): Clocks affected by satellte speed relartive to earth frame of reference
- General Relativity (GR): Clocks affected by differences in gravitational firld between satellites and receivers
- SR effects compensated by adjusting satellite clock divider ratios - different ratio for rubidium/cesium clocks on satellites and on earth

Derived Navigational Information

- Lat/Lon in degrees, UTM, other units
- Local time, UTC, elapsed time, ETA, ETE, altitude
- Speed, heading, bearing (true or magnetic) all in land or marine terms (SPD/SOG, HDG/COG, Landmarks/Waypoints, etc.)
- Distance to destination, distance traveled
- “Bread crumb” trail

Types and Cost of GPS Receivers

- Hand-held, “watch”, car and boat mounted, PDA attachments ($100 - $1,000)
- Built into cars with voice guidance, maps, street and address software with road lock, inertial navigation and DGPS ($1,000 - $3,000)
- For land surveys with Carrier Phase Comparison and Postprocessing ($5,000 - $20,000)
- Military with PPS and S/A decryption ($???)

Portable GPS Receivers ($100 - $1,000)

Portable GPS Receivers

Etrex Summit, with electronic digital compass, barometer and altimeter

Features in $100 - $1,000 Price Range

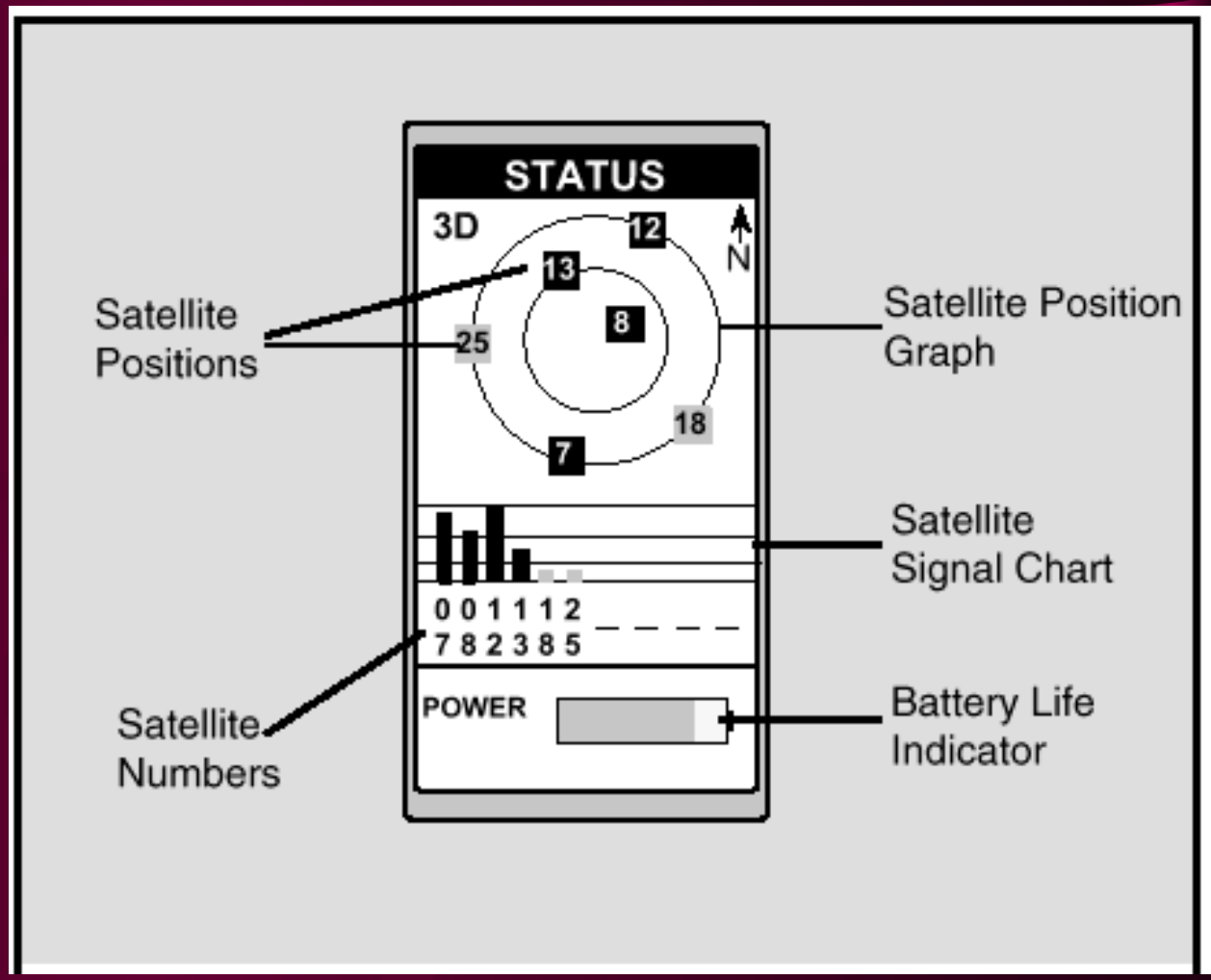
- Small manufacturers - Garmin, Magellan, Lawrence
- Not much advertising - little awareness, except for boat owners and hikers
- Storing of waypoints, routes and tracks
- 8 - 15 display screens with context sensitive menus
- Color display, back light
- Depending on price range - user waypoints only, built-in city waypoints, fixed maps, maps on cartridges, maps downloadable from CDs

Additional Features in $100 - $1,000 Price Range

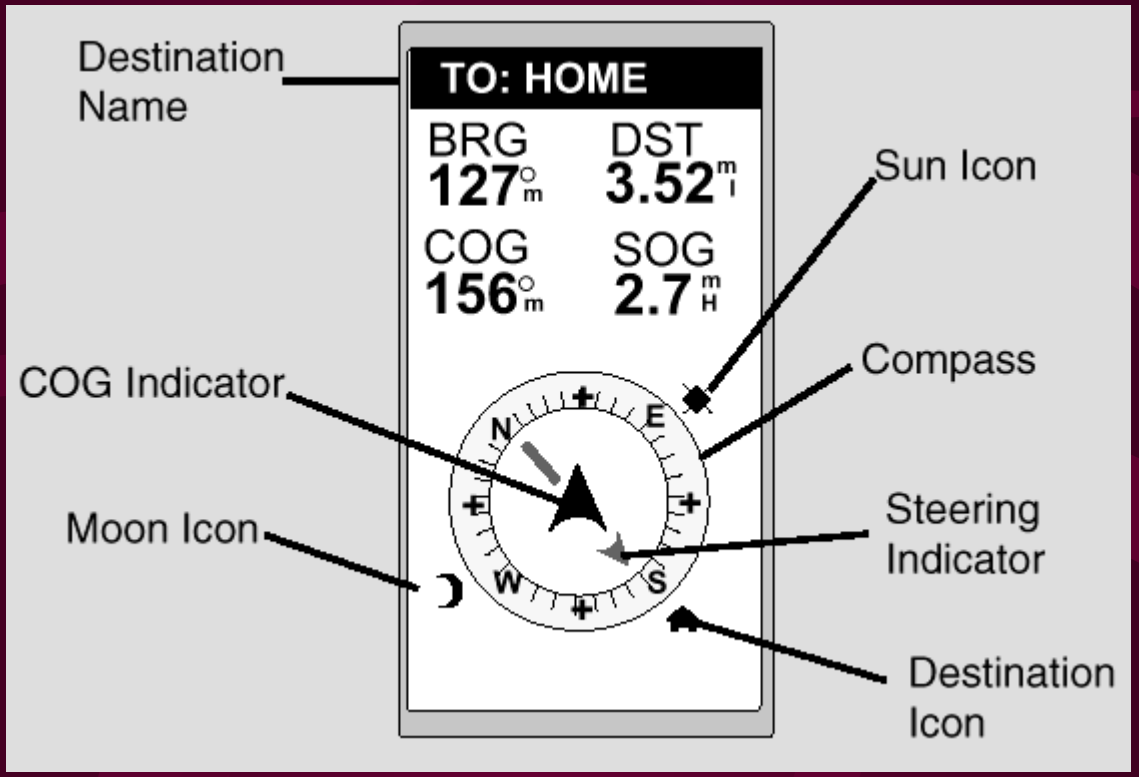
- Parallel input for up to 12 satellites vs. multiplexed input
- Selection of map datums, coordinate systems
- Simulation
- 100 - 500 waypoints
- 10 - 50 routes with back tracking, MOB
- Sun/Moon rise and set, moon phase, dynamic display
- Wide range of scales on map display (0.1 - 1,000 mi)
- Precise clock, proximity and other alarms

Satellite Status

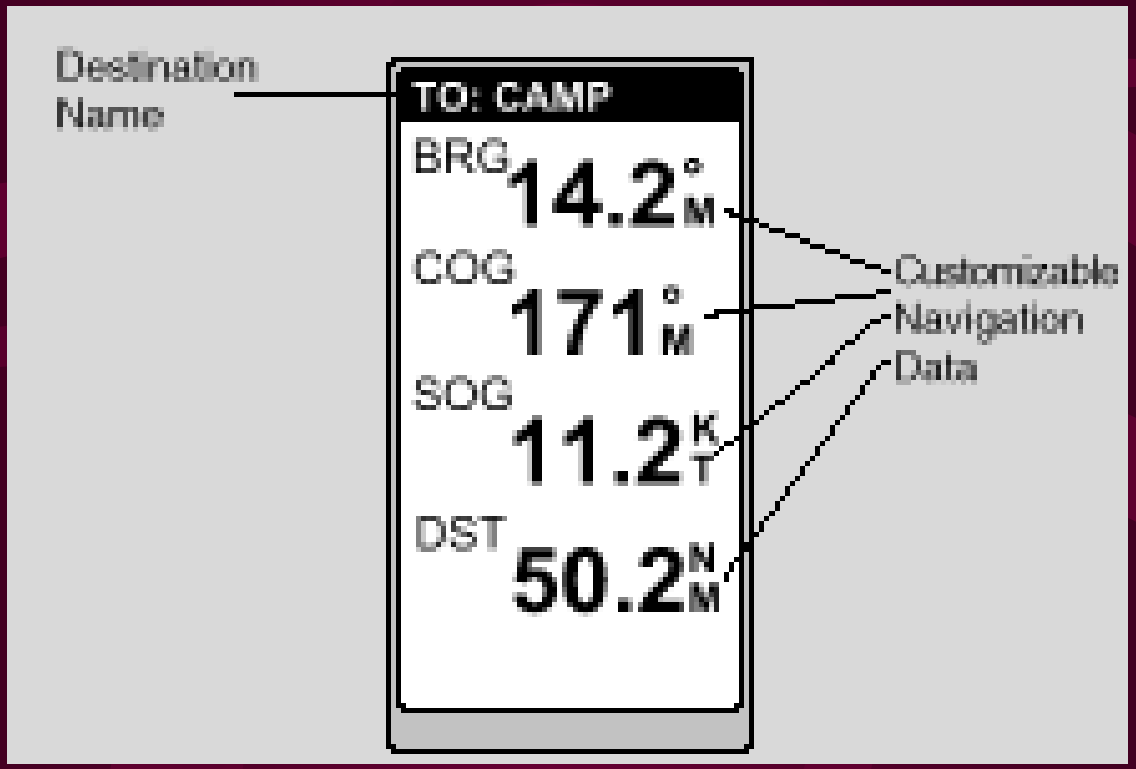
- 5,300 mi horizon



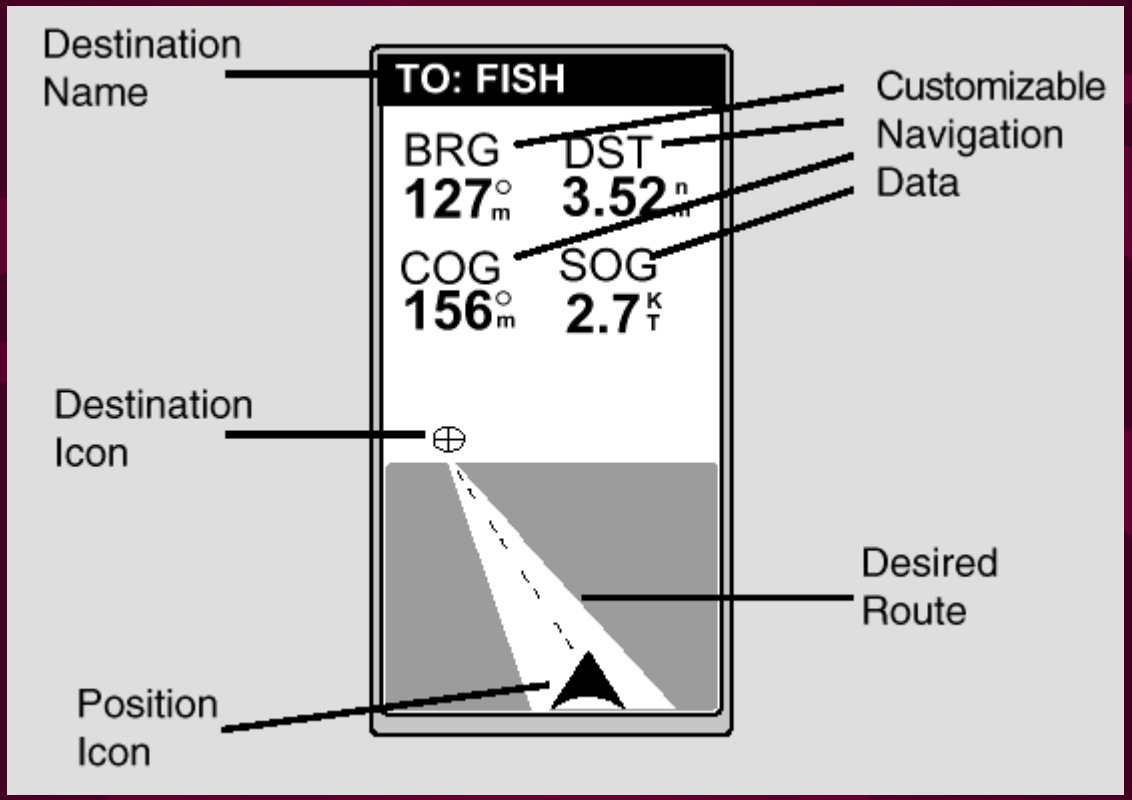
Compass Rose



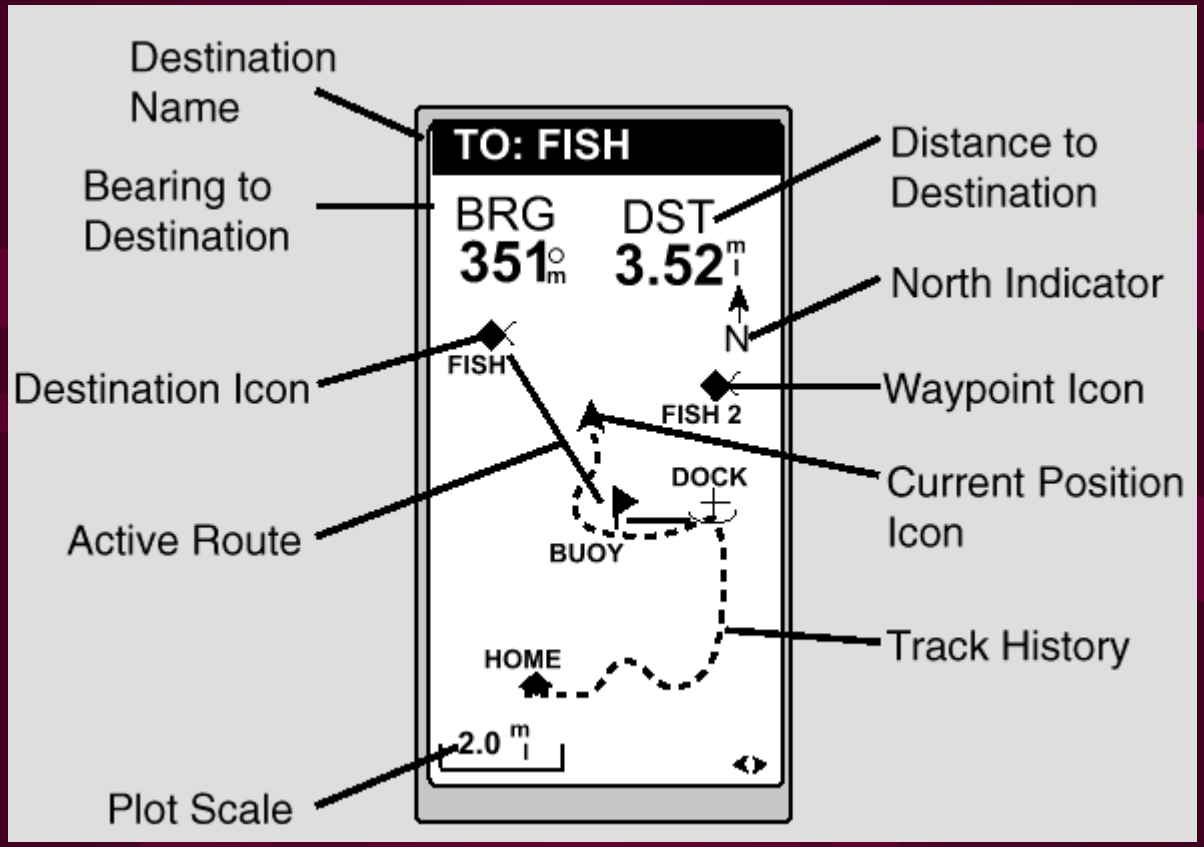
GoTo Large Screen



Alternate GoTo Screen

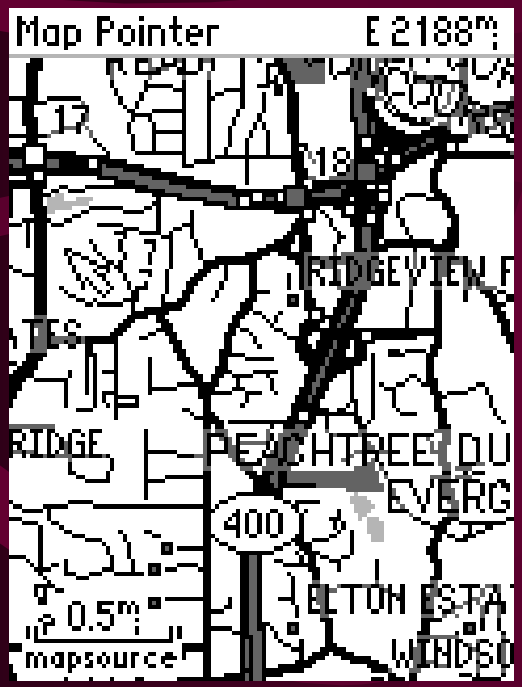


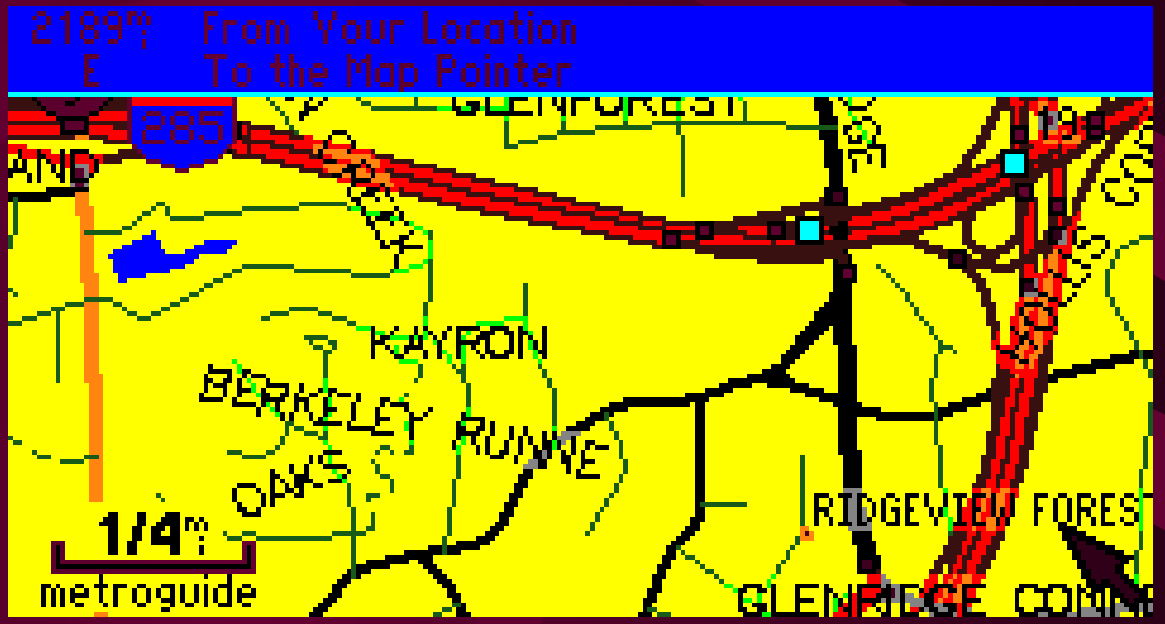
Graphical Position Display (without map capability)



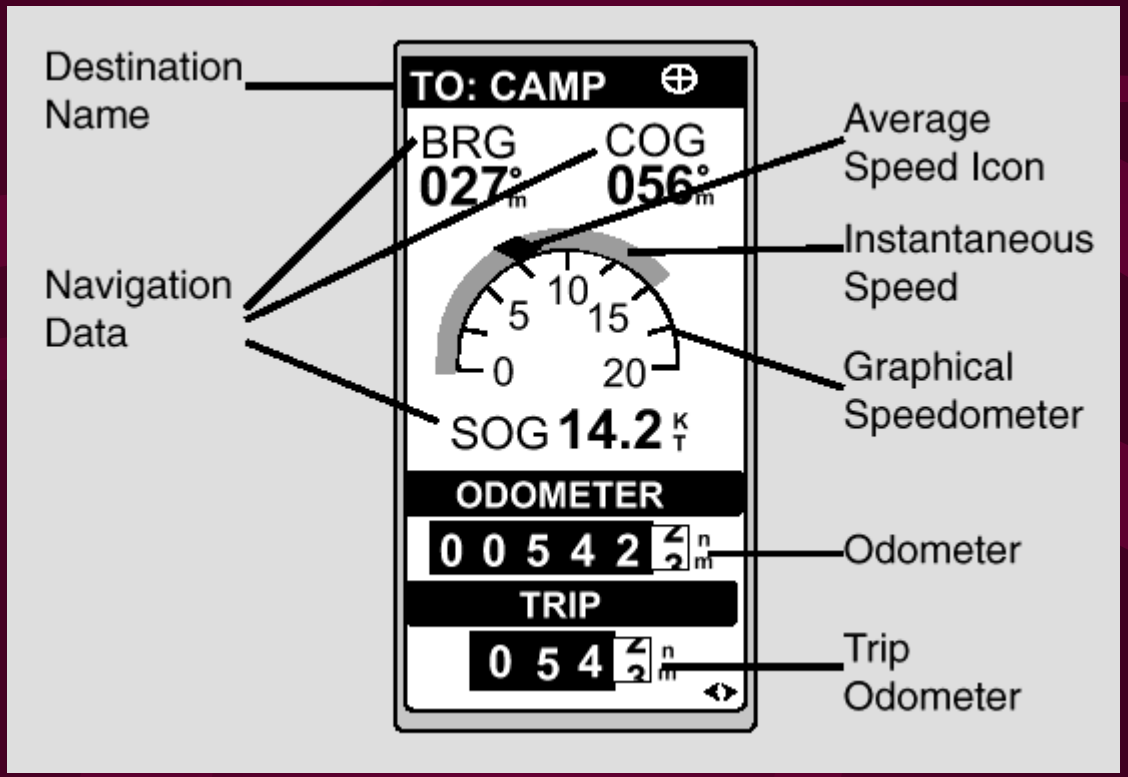
Graphical Position Display (with map capability)

- B/W and Color Map Displays

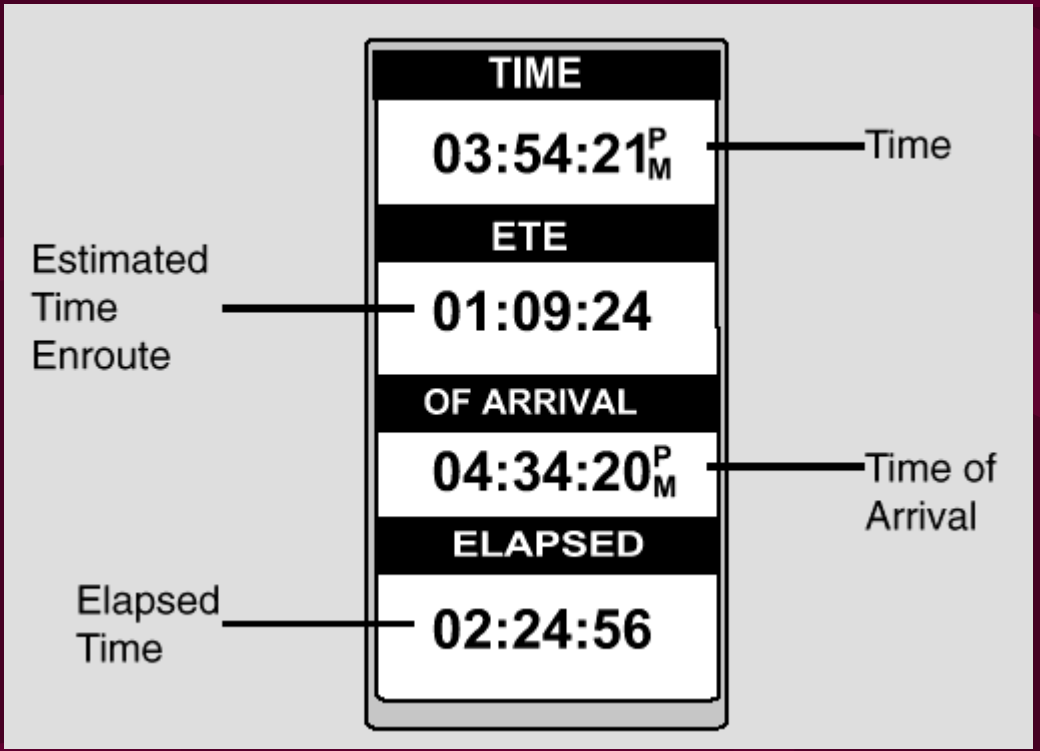




Tachometer/Odometer Screen



Time Screen



Flash Memory Usage

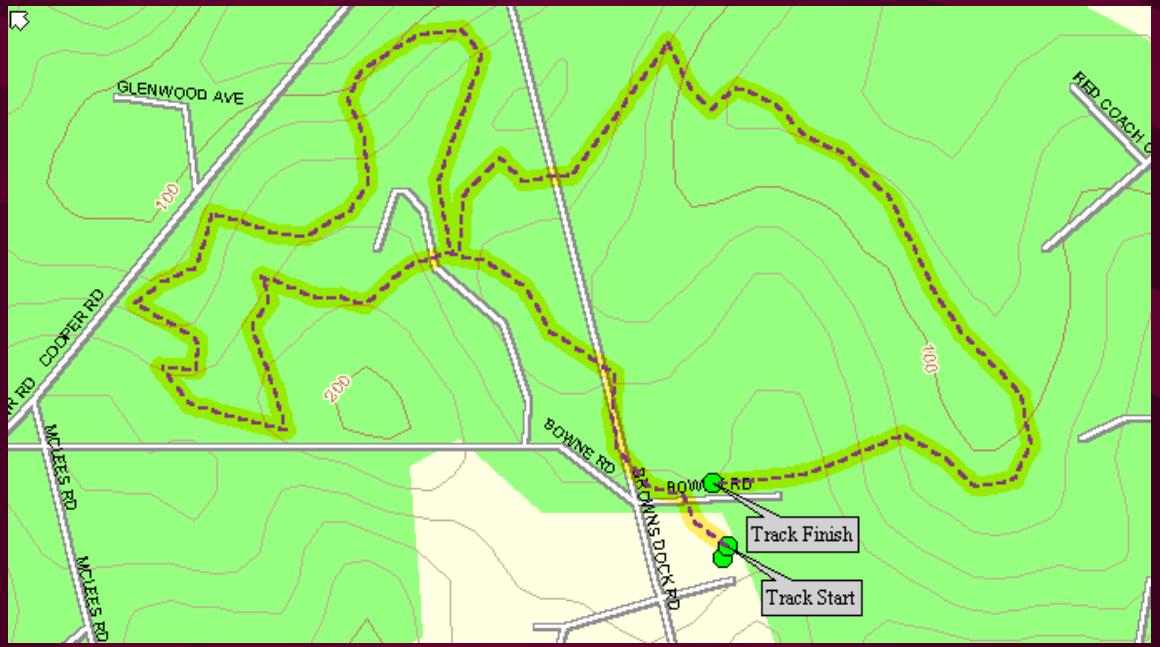
- Example - Magellan SporTrak Pro - 9 Mb reserved for OS and basic map, 23 Mb reserved for detailed maps, waypoints, routes and tracks
- Installation of detailed maps only possible with proprietary protocols and specific (and expensive) manufacturer's software
- Access to user data (waypoints, routes, tracks, current position) available to most commercial software

Hiking and Driving with a GPS

- Heading - direction of travel, Bearing - direction to a waypoint
- Using a compass, compass rose on GPS (>5 mi/h speed required for accurate heading indication), dynamic Sun/Moon display
- Making turns when Bearing and Heading differ by, e.g., 90 deg
- Marking trail head and trail crossings
- Horizontal accuracy - 100 ft or better (after 05/01/00).

Transferring a Hike to a Topo Map

- Uploading tracks to a mapping program, e.g., to TOPO USA on the desktop PC (Huber Woods)



GPS On A Commercial Flight

- Hold against window - a great sensitivity test
- Know where you are, speed, altitude
- Flight attendants: negative attitude
- Captain: “You can use it, if you tell us if we are off-course.”

GPS/PC/PDA Connection

- RS-232 serial port 1,200 - 19,200 bps, also USB
- NMEA and proprietary protocols
- Software for the moving map display, waypoint, track and route saving, locating addresses
- Operating system upgrades distributed via Internet
- GPS software: commercial (Street Atlas, Solus, ProComm), shareware (Ozi Explorer) and free (MagWay, EasyGPS)
- Topo maps on CDs and on cartridges

GPS on the Web

- General links - www.joe.mehaffey.com
- Usenet - sci.geo.satellite-nav
- Address search - http://www.mapsonus.com http://www.geocode.com/eagle.html-ssi (don't forget to convert ddd.dddd to ddd.mm.ss!)
- Manufacturer and vendor web pages

Power Sources

- 2 - 6 mostly AA batteries, 100 - 200 mA drain
- Primary - Alkaline (2,000 mAh), Lithium (3,000 mAh)
- Rechargeable - NiCad (450 - 800 mAh), NiMH (700 - 1,200 mAh). Manufacturer specs not reliable
- Factors for selection - battery capacity, charging memory, temperature dependence, weight and price
- Cigarette lighter cable with voltage regulator (10-14V converted to 3V)

Where Do We Go From Here

- New generation of satellites
- Use in civil aviation
- Use for cellular phones
- Privacy concerns (1984)

Brookdale Computer User Group (BCUG)

- Group of 300+ volunteers interested in computers
- BCUG is is a non-profit organization not associated with Brookdale Community College
- Monthly general meetings at Brookcale campus in Lincroft, NJ
- Monthly newsletter, special interest group activities
- Dues are $25/year, $20 for non-working retirees
- For more information: http://www.bcug.com