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Market Diversification & Use Case Overview

AUTOMOTIVE | OUTDOOR | FITNESS | MARINE | AVIATION

Use Case - Aviation

AVIATION

- Installed, OEM and portable flight decks and avionics for airplanes, helicopters and light aircraft
- Satellite weather, traffic and radio and terrain awareness
- Nav/Comm, transponders, indicators, audio panels, altimeters

Garmin's aviation GPS products support both surface and airborne applications. Garmin produces FAA certified and non-certified equipment for the General Aviation market, including both fixed-wing and rotorcraft platforms.

Aside from instrument approach procedures, Garmin's non-certified aviation products perform the same operations as our certified aviation products

Unmanned Aerial Vehicles (UAVs) are an emerging platform that is greatly dependent on GPS. UAVs may operate at low altitudes and in areas different from normal aviation operations.

Receiver Characteristics (certified)

- Compliant with FAA TSO-C145/146
- Permanently installed in aircraft
- Antennas comply with FAA TSO-C144 and are externally mounted on the top of aircraft.
- Antenna heights range from a few meters up to maximum operating altitude of aircraft.
- Operating speeds from 0 – 800 knots (411 m/s)
- Used in urban and rural environments

Receiver Characteristics (non-certified)

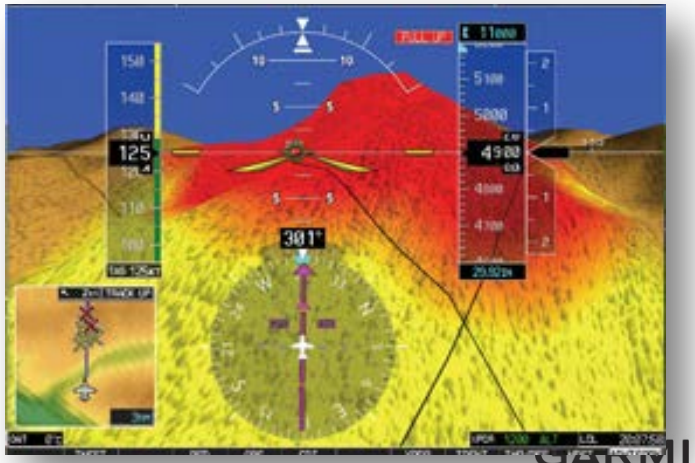
- Receivers may be permanently installed in aircraft or portable
- May use integrated antennas or externally mounted active antennas
- Same operating altitudes and speeds as with certified equipment
- Used in urban and rural environments

GPS Has Improved Aviation Safety

- Over 80% of the U.S. fleet of General Aviation aircraft are equipped with GPS.
- GPS provides reliable and accurate navigation.
- GPS enables enhanced Situational Awareness.
- GPS is a key component in Hazard Avoidance, including Terrain Avoidance and Warning Systems (“TAWS” for fixed and rotary wing aircraft), which provide timely alerts that prevent aircraft from flying into the ground.
- GPS is the backbone of the FAA’s NextGen program.

TAWS and HTAWS

- Critical safety feature to reduce Controlled Flight Into Terrain (“CFIT”) accidents.
- Integrated with Synthetic Vision Technology for real-time terrain awareness and warning.
- Voice callouts help enhance situational awareness while allowing the pilot to focus on flying.
- Designed to alert flight crew of operation outside of the normal safe envelope – consequently, they need to work <u>everywhere</u>.
- Mandatory equipment for commercial aircraft.



Weather Avoidance

- GPS enhances pilots' situational awareness with respect to adverse weather conditions.
- Weather data are available from several sources and include: High-resolution NEXRAD imagery, METARs, TAFs, precipitation, lightning strikes, storm cell data and other weather updates for the entire U.S.

NexGen and ADS-B

- NextGen relies on precise GPS position transmitted over an RF datalink (UAT or Mode S) to replace conventional, radar-based surveillance as the primary method for identifying and tracking aircraft in U.S. airspace. All aircraft will be required to support ADS-B “Out” by 2020.

Additionally, aircraft with ADS-B “In” capability can track the position and altitude of nearby aircraft.

SafeTaxi

- Hazard avoidance is not limited to the air. GPS also improves aircraft safety on the ground.
- Garmin's SafeTaxi identifies runways, taxiways, FBOs, and hangars, as well as an aircraft's exact location on the field.

Use Case - Marine

MARINE

- OEM, handheld and wrist-worn chartplotters, fishfinders and sounders for boating, sailing and fishing
- Charts, CHIRP sonar technology (high definition), satellite weather
- Radar, autopilot, cameras, sailing instruments, transducers

- Receivers may be permanently installed or portable
- May use integrated antennas or externally mounted active antennas
- Variable speed applications dependent on platform
- Antenna heights are low (< 30m)
- Applications include both open water and inland waterways in urban environments
- With the US termination of the Loran program, GPS is the primary radio-navigation aid available for marine applications

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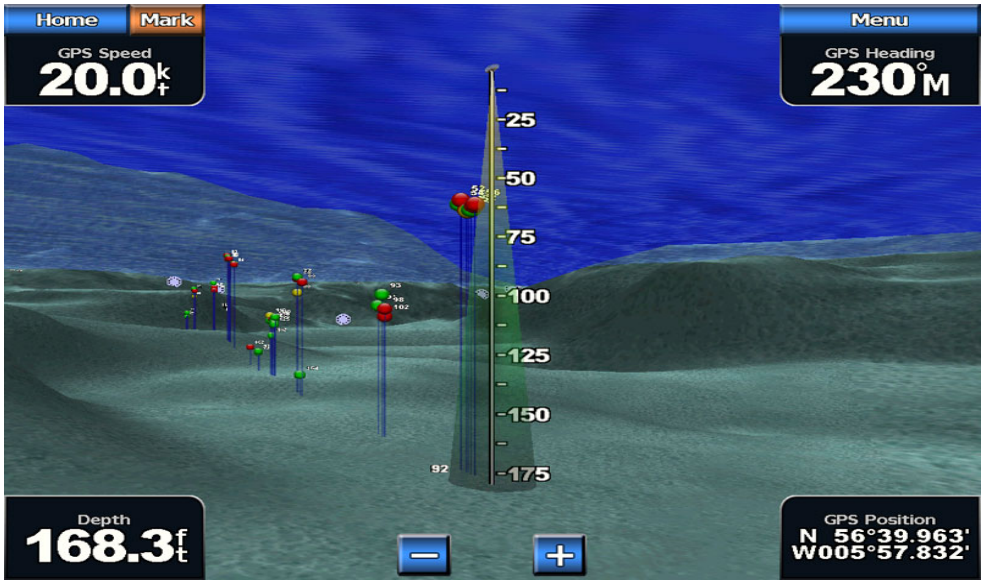
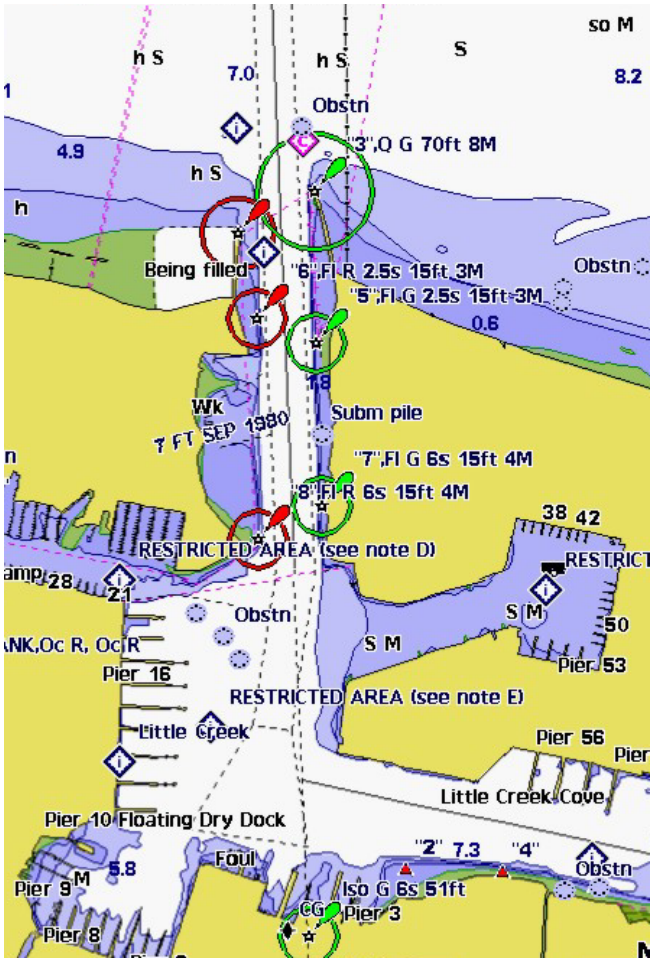
Marine Charts

- Basic charts, tidal stations, currents, depth contours, IALA symbols and bathymetric contours (underwater topography contours)
- Rely on GPS for accurate positioning, hazard avoidance, and safe navigation.
- When GPS is compromised, safety is compromised.





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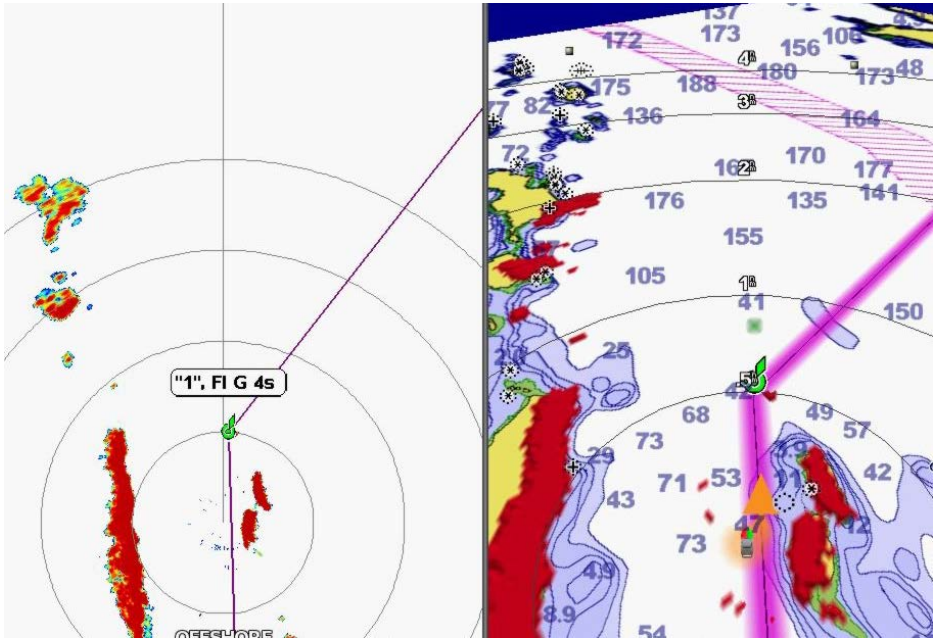
Marine Radar

- High sensitivity radar provides consistent target positions and excellent target separation for improved safety overnight and in foggy, limited or no visibility, conditions.
- Relying on GPS for reference positioning, radar paints a clear, concise image of the shoreline, other vessels, and impending weather, thereby improving situational awareness and safety.



Marine Autopilot

- Relies on GPS position and heading to maintain control of the vessel and keep it on course while the captain and crew attend to other duties
- Enhanced safety for crew and nearby vessels

Use Case - Automotive

AUTOMOTIVE

- Personal navigation devices for vehicles, including motorcycles, trucks and RVs
- OEM hardware, software and infotainment solutions, Fleet Management and Tracking
- Dashboard and backup cameras, windshield navigation projection
- Mobile navigation applications

- Receivers generally mounted in or on a vehicle
- May use integrated antennas or externally mounted active antennas
- On and off-road operation in both urban and rural environments
- Receiver proximity to multiple wireless devices is often less than one meter.

Use Case - Outdoor

OUTDOOR

- Handheld and wrist-worn devices for:
  - Search and Rescue
  - Hunting
  - Hiking, Camping
  - Dog training
  - Geocaching
  - Golfing
- HD Action Camera
- Two-way radios

- Portable receivers may be carried, worn, or attached to equipment or animals
- Rugged and reliable products are used for recreation, hunting, and search and rescue operations as well as by military and law enforcement
- Receivers use integrated antennas unique to each application
- Receiver proximity to wireless devices can vary from centimeters to meters

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Use Case - Fitness

FITNESS

- Wrist-worn, mounted, and pedal devices for wellness, running, cycling, swimming, and multi-sport
- Heart rate monitoring, foot pods, speed/cadence sensors
- Track, store and share fitness activities on Garmin Connect

- Portable receivers may be worn or attached to equipment such as bicycles or golf carts
- Receivers use integrated antennas
- Receiver proximity to wireless devices can vary from centimeters to meters
- Receivers that may be worn also have law enforcement and public safety applications

Appropriate Test Metrics and Need for Forward Looking Study

Navigation vs. Communication Systems

- GPS is a navigation system and differs from radio communications systems.
- The primary measurement in GPS is the timing of bit transitions in the navigation signal.
  - Precise positioning requires sub-ns measurements of bit edges
  - Accurate measurement of bit edges requires wide receiver bandwidth
  - Effective multipath rejection also requires wideband signals
- Spread Spectrum GPS signals are below the thermal noise floor (the level of noise occurring naturally and apart from manmade sources) when received.
  - The cumulative effects of in-band interference can increase the noise floor and degrade performance.

Excessive Impairment

There is widespread consensus on the level of degradation that impairs GPS/GNSS signals in the RNSS band.

- The communications industry has long held to a 1 dB increase in the noise floor as the standard for the maximum tolerable level of harmful interference.
- The reports and findings of NTIA (based on input from other agencies) in the recent LightSquared testing conducted at the end of 2011 continue to affirm that a 1 dB decrease in C/N_0 constitutes harmful interference to GPS.
- Degrading C/N_0 by 1 dB will result in deleterious effects on GPS receivers:
  - Diminished acquisition sensitivity
  - Degraded time to first fix (TTFF)
  - Reduced performance in the urban canyon, in buildings, or under foliage
  - In challenging signal environments, 1 dB of signal strength can be the difference between tracking a satellite and obtaining an accurate fix, or not tracking a satellite and obtaining a much less accurate fix or no fix at all.

Other Global Navigation Technologies

- The United States' Global Positioning System "GPS" is one of several Global Navigation Satellite Systems ("GNSS") deployed by various countries. Other systems include:
  - Galileo (EU)
  - Beidou/Compass (China)
  - GLONASS (Russia)
- The United States will begin to deploy an updated and modernized L1C code with Block III satellite launches beginning in 2016.
  - L1C, along with Galileo, GLONASS, and other modern GNSS systems, requires wider receiver bandwidth than traditional L1 C/A code receivers.
  - This is due to the fact that the L1C signal will be transmitted in a wider bandwidth, thus allowing consumer-grade GPS receivers to offer significantly improved positioning performance.
  - These wide bandwidth signals will be even more susceptible to interference if high-power terrestrial transmissions are allowed in adjacent bands

Receiver Performance

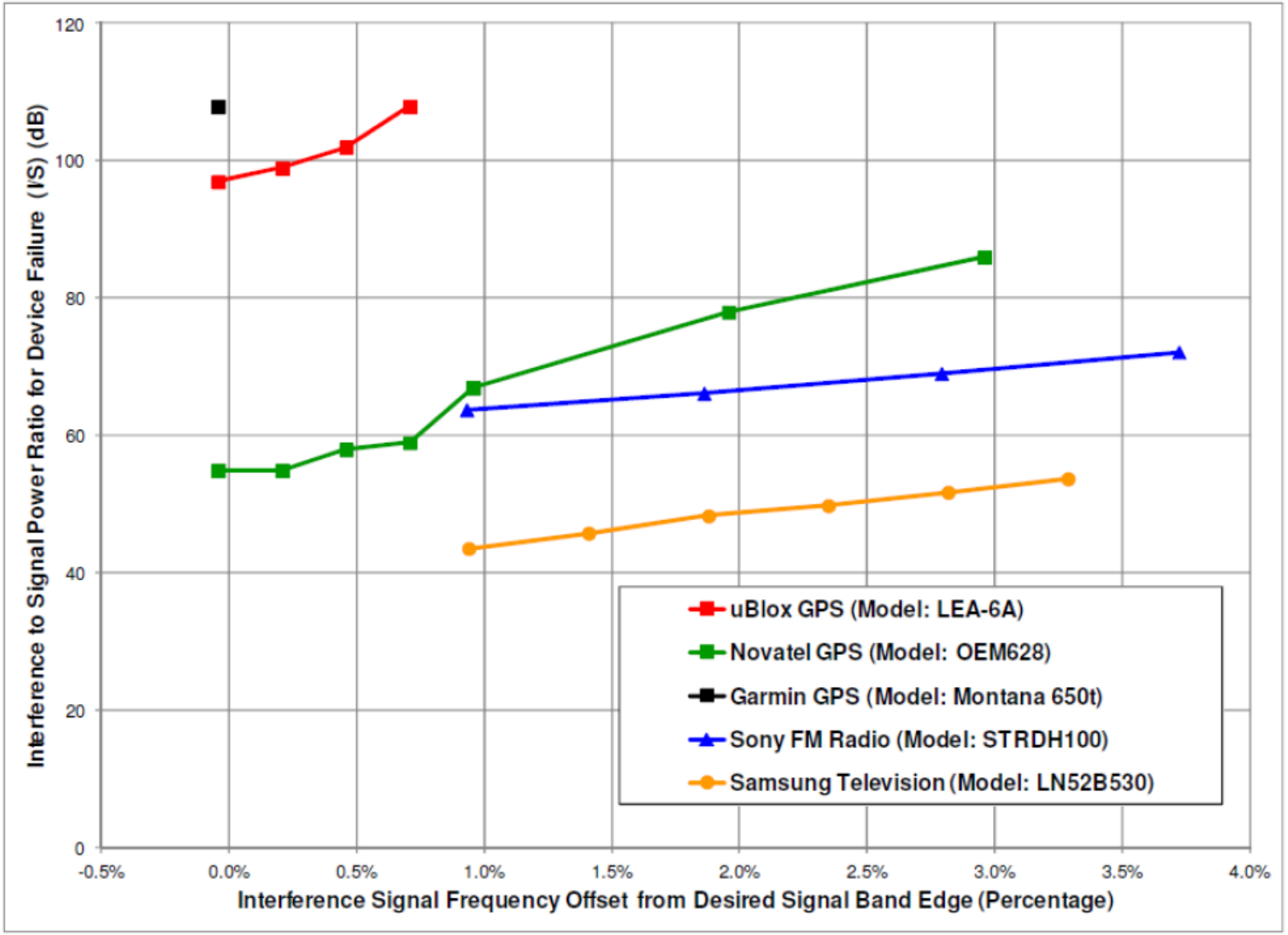
The GPS industry has a long track record of innovation and technological advancement.

- Manufacturers are continually improving receiver sensitivity, adjacent channel selectivity, and positioning algorithms.
- The US Government is also continually improving the GPS constellation in order to provide the maximum utility in its existing spectrum.
  - L1C, for example, will allow commercial GPS receivers to take advantage of a wider swath of spectrum in order to achieve better, more accurate positioning performance.
  - This will require wider bandwidth filters, making high-power, intensive use of adjacent spectrum even more of a concern. It is therefore insufficient to simply create a mask based on today's filter capabilities.
- In order to protect this innovation, certainty in the adjacent spectrum is needed, in the form of stable and well defined power limits.

GPS Receiver Performance

- The differences between satellite/navigation and terrestrial/communication systems do not mean that GPS receivers are poorly designed.
- In fact, recent studies have shown that GPS receivers have more robust interference rejection capabilities than other mass-market terrestrial receivers
- In May 2013, the Aerospace Corporation tested a number of common consumer radio receivers against adjacent band interference signals
  - *Digital Television (Samsung LN52B530)*
  - *FM Radio (Sony STRDH100)*
  - *3 types of GPS receivers*
    - Garmin Montana 650t,
    - uBlox LEA-6A,
    - Novatel OEM 628
  - http://www.gps.gov/governance/advisory/meetings/2013-05/powell.pdf
- All testing was conducted in a controlled, laboratory environment

Aerospace Receiver Test Results



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