Garmin Offers a Myriad of Devices in Five Markets

The applications span many design constraints, such as low power, small size, and form factor. Each has unique requirements to serve the required function.

### AUTOMOTIVE
- Personal navigation devices for vehicles, including motorcycles, trucks and RVs
- OEM hardware, software and infotainment solutions
- Dashboard cameras, windshield navigation projection
- Mobile navigation applications

### OUTDOOR
- Handheld and wrist-worn devices for:
  - Hunting
  - Hiking, Camping
  - Dog training
  - Geocaching
  - Golfing
- HD Action Camera
- Two-way radios
- BirdsEye satellite imagery

### 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

### 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

### 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
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.
• There are many differences between low-power satellite systems and high-power terrestrial broadband systems.
  – Space-to-Earth Satellite systems are designed to accommodate low-power signals received from distant satellites in space.
  – Mobile broadband networks, on the other hand, are designed to utilize high-power terrestrial signals broadcast from tens of thousands of towers around the nation.
  – If placed in adjacent bands, the high-power terrestrial signals from mobile broadband networks would overwhelm low power satellite signals. This overloading would impair the functioning of these systems.
GPS Receiver Specification

• Low Noise Amplifiers (LNAs) specifications primarily driven by market segment: what performance is required to enable best-in-class consumer and aviation products

• Important characteristics of front end components:
  – Physical size of LNA and filters
  – Power consumption
  – Gain / noise figure
  – Linearity / compression
  – Adequate bandwidth for multi-constellation support while also rejecting interference within the known spectrum environment (e.g., cellular bands, Bluetooth/WiFi)
  – Phase / group delay across passband
  – Receiver front-end requirements vary by market segment (e.g., high precision devices have wider bandwidth than consumer devices.)

• Recent empirical work has shown that GPS receivers have more robust interference rejection capabilities than other mass-market terrestrial receivers. See http://www.gps.gov/governance/advisory/meetings/2013-05/powell.pdf

• Receiver standards would stifle innovation and slow technological advancement.
Modernized GNSS

- 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.
  - The longer codes used in this modern signal design provide increased performance to improve GPS reception in cities and other challenging environments.

- New GPS satellites also support new civilian signals on other frequencies
  - L2C (1227.60 MHz) and L5 (1176.45 MHz)
  - Dual frequency operations can improve accuracy and provide some redundancy against unintentional interference which will benefit public safety users needing high availability of service.
  - Galileo, GLONASS and other GNSS systems will also provide multiple civil signals

- Multi-constellation receivers will provide benefits to user
  - Increased number of visible satellites improves availability in challenging environments
  - Additional redundancy can protect against system failures, improving overall integrity with corresponding benefits to safety.

- The consumer space is moving towards modernized signals (L1C) and multi-constellation/multi-frequency to drive even better performance and new applications
Certified Aviation Perspective

- GPS has improved aviation safety
  - TAWS is a critical safety feature that relies on GPS and has dramatically reduced controlled flight into terrain “CFIT” accidents
  - ADS-B and NextGen are replacing conventional radar-based surveillance with more accurate GPS-based positioning. All aircraft in controlled airspace will be required to support ADS-B by 2020.
  - GPS position combined with real-time weather data allows pilots to avoid hazardous weather conditions

- FAA imposes standards for aviation GPS to ensure performance and safety
  - Requirements for sensitivity, dynamic range, accuracy, and interference rejection across a wide range of environmental conditions.
  - Detailed requirements for receiver bandwidth, correlator spacing, differential group delay, positioning and integrity algorithms constrain design space.
  - Performance standards are tailored for aviation use and not universally applicable.

- Compliance with these requirements is costly and time consuming
  - Need for detailed design and verification data complicates use of 3rd party chipsets.
  - Expensive certification process = expectation of service life of 10-20 years or more.

- FAA standards will evolve to incorporate modernized GNSS signals
  - New signals will increase availability and integrity of GPS/GNSS service for safety-critical airborne receivers.