Satellite Navigation: GPS Modernization and R&D in the Academic Sector

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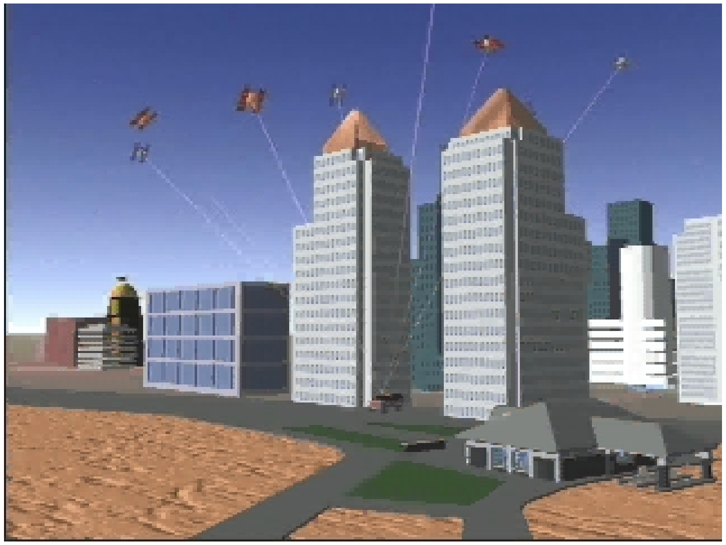
Outline

- GPS Weaknesses
- GPS Modernization
- The Shrinking GPS Receiver
- GPS and E-911
- The Future of GPS Technology
- GPS R&D at Canadian Universities

GPS Weaknesses

- C/A-code only on L1: no dual-frequency ionospheric delay correction
- L1 and L2 signals not afforded total spectrum protection
- GPS signals relatively weak (actually buried in background noise)
  - Signals cannot readily penetrate into concrete and steel buildings or underground
  - Signals can be blocked by buildings and other structures
  - Susceptible to interference or jamming
- Reflected signals (multipath) cause position error

Signal Blockage



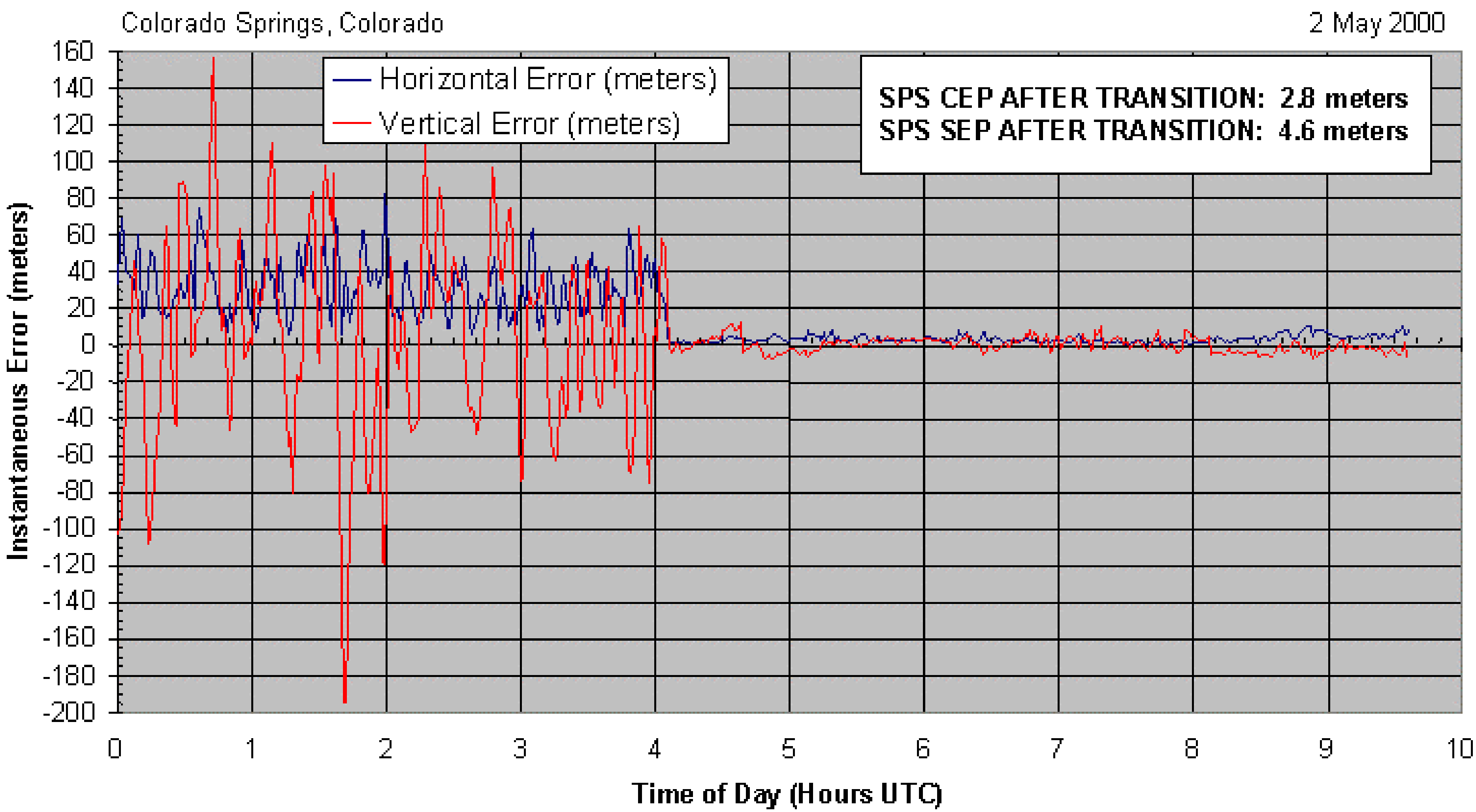
Tall buildings can block GPS satellite signals

Reduced satellite visibility increases geometrical dilution of precision resulting in reduced positioning accuracy

GPS Modernization

- One goal is enhanced capabilities for civil users of GPS
- Civil benefits include:
  - Selective Availability (SA) turned off on 2 May 2000
  - Second civil frequency for ionospheric correction and redundancy
  - Third civil signal for "safety of life" applications in protected spectrum; more robust; also provides high accuracy and benefits real-time applications

Selective Availability Switched Off



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GPS Modernization Details

- Last 12 Block IIRs - Add second civil signal (C/A on L2) and new military signal (M-code). Provide more signal power.

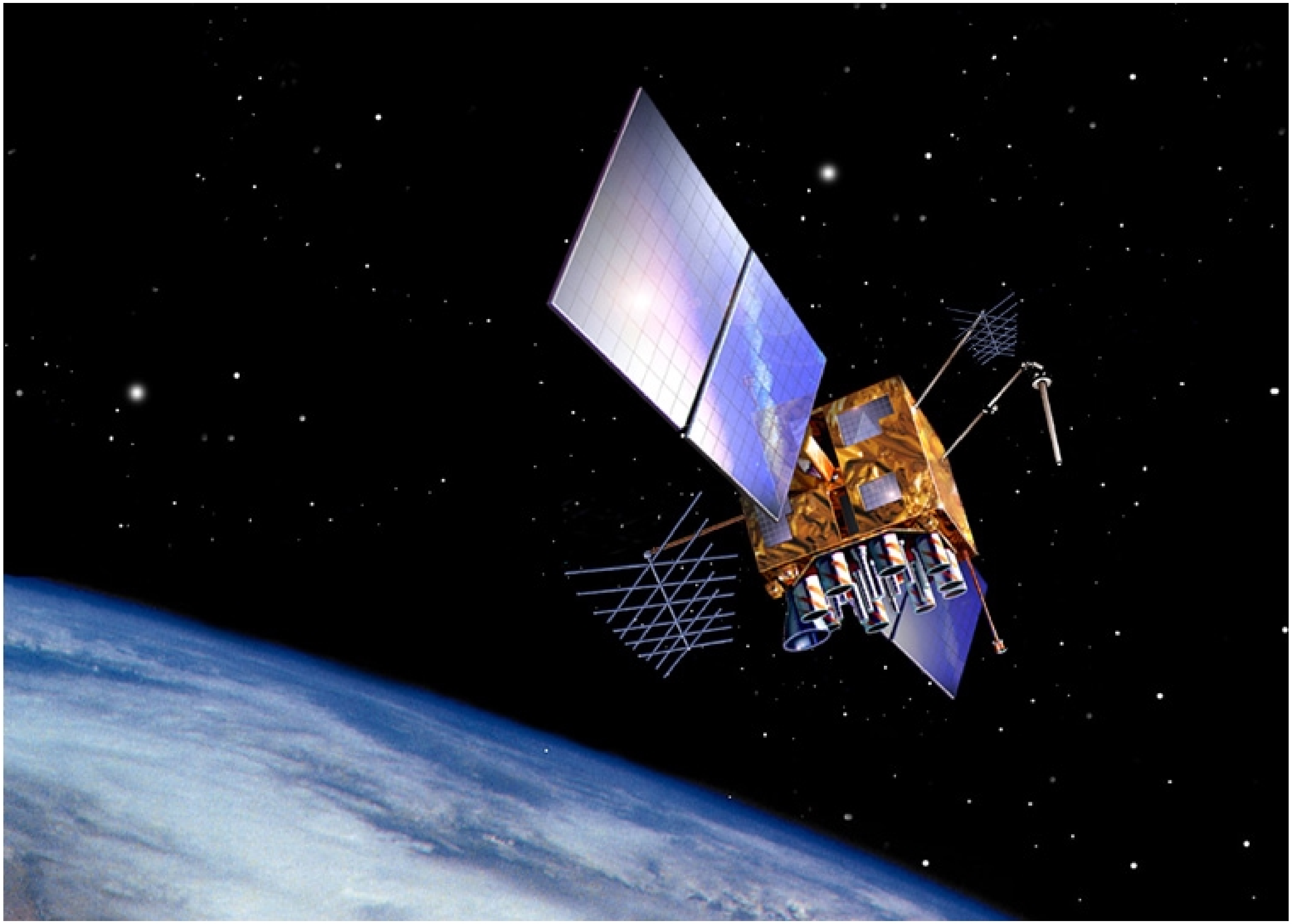
  First modernized launch (Block IIR-M) - FY03

- First 6 Block IIFs ("IIF Lite") - All of above capabilities plus new third civil signal in protected band (L5).

  First Block IIF "Lite" launch - FY05

- At the current GPS satellite replenishment rate, all three civil signals (L1-C/A, L2-C/A, and L5) will be available for initial operational capability by 2010, and for full operational capability by approximately 2013.

Block IIR Satellite



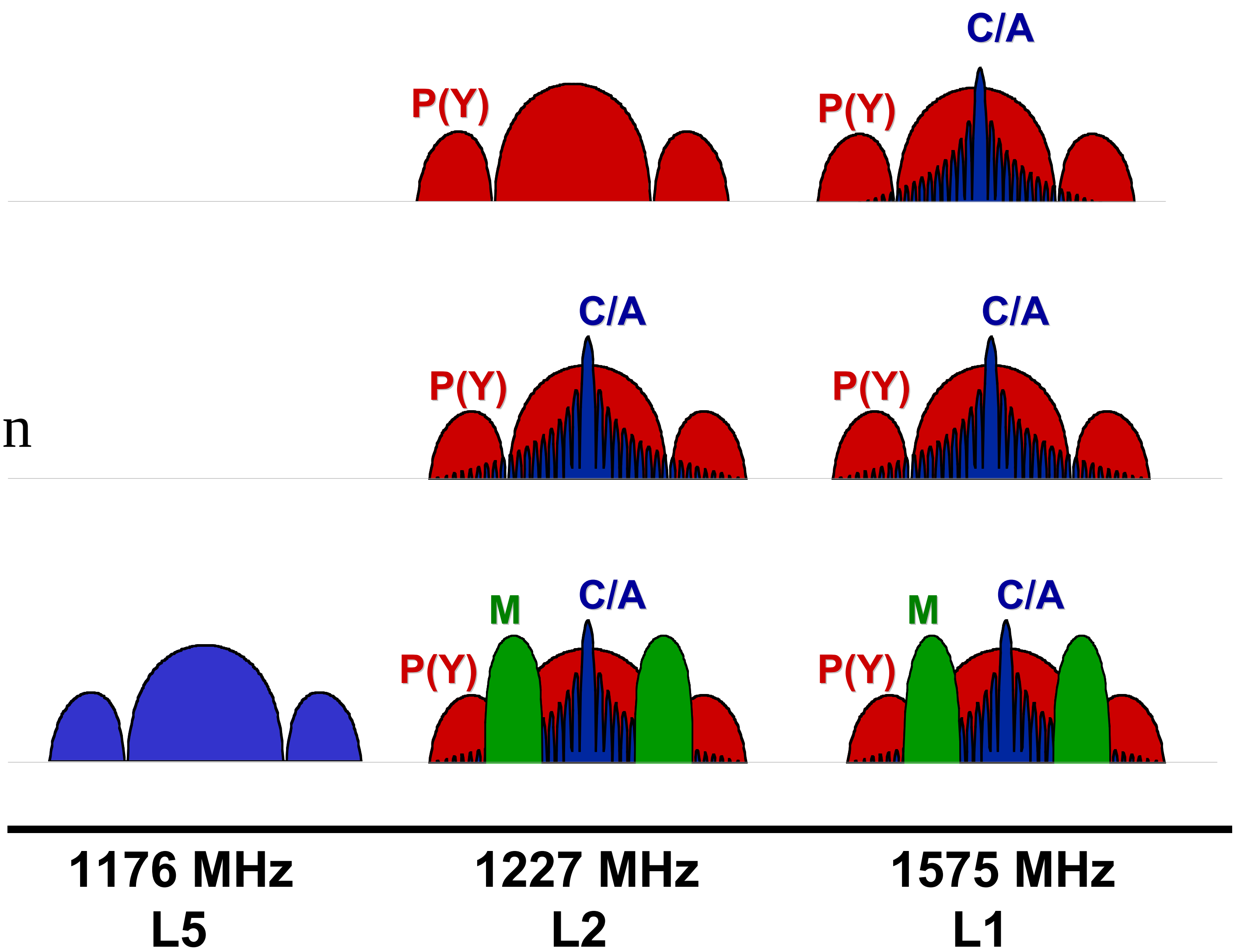
Block IIF Satellite

Signal Modernization

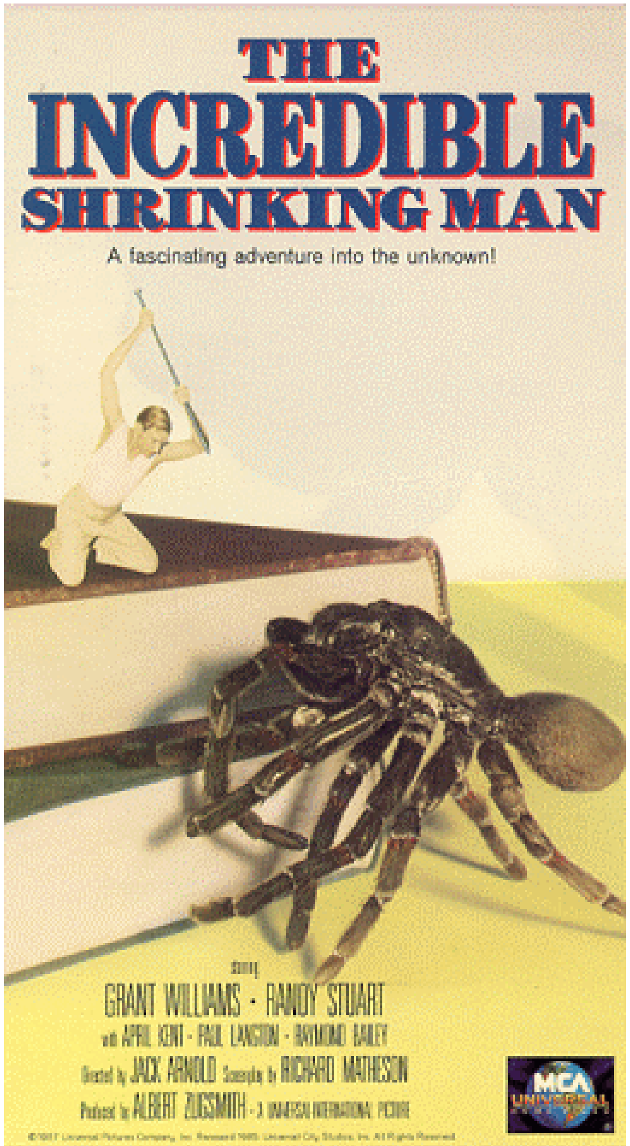
Present Signal

Civil Non-Aviation Signal (>2003)

Civil Aviation & New Military Signals (>2005)

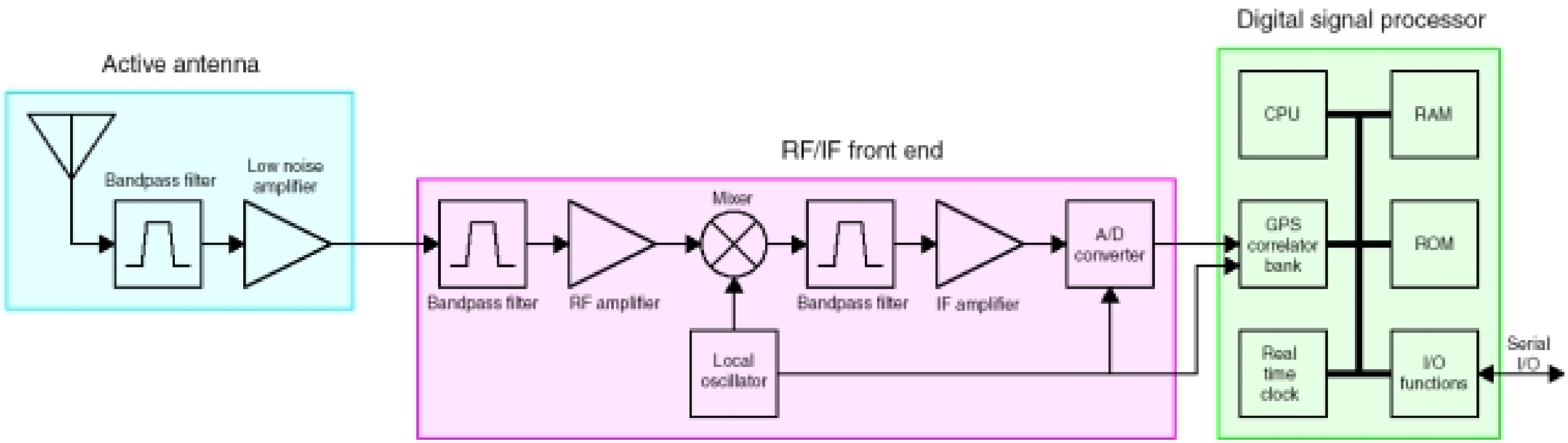


The Incredible Shrinking GPS Receiver



- First commercially available GPS receivers, circa 1980, consisted of two 19-inch racks of electronics
- In 1982, first “portable” receiver introduced; weighed 25 kg and consumed 110 watts of power
- First large handheld receivers introduced in 1988
- 1993: multi-chip module prototype
- 1999: GPS watch

“Two Chip” GPS Receiver



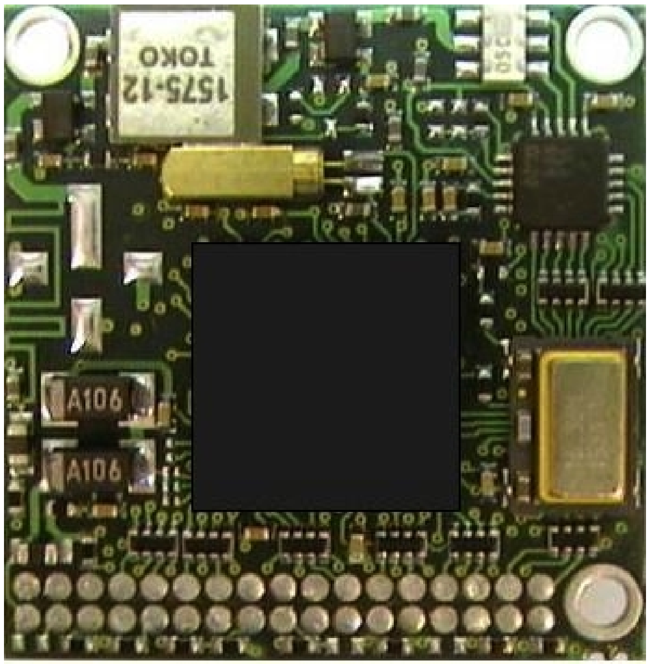
AxiomNavigation Swift B1 OEM Receiver

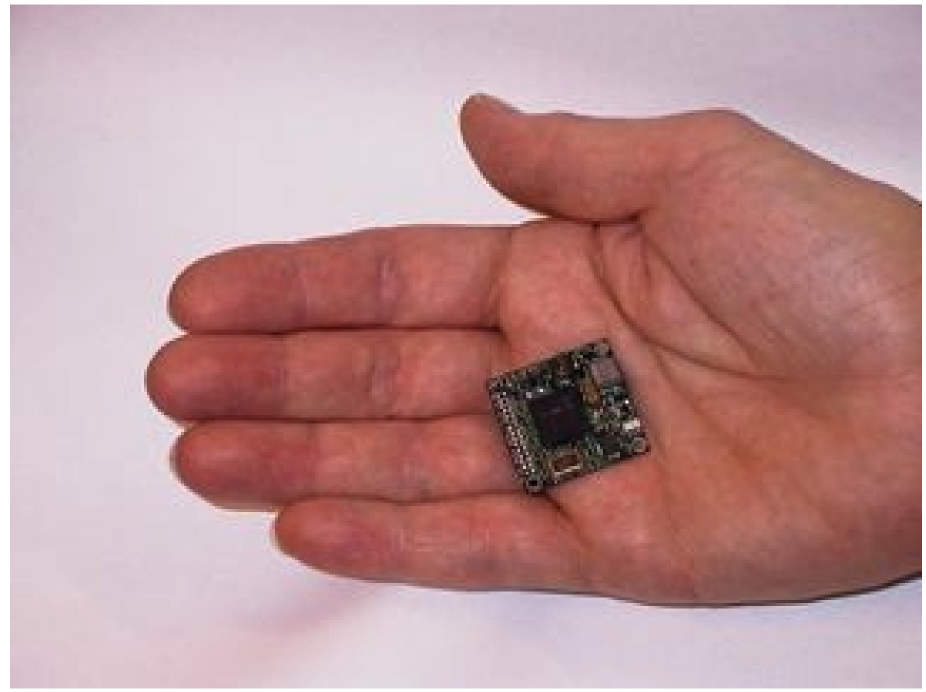
- OEM module
- Based on SiRF 2nd generation chip set

iTrax02 GPS Receiver Module

|----------25 mm---------|

25 mm





Casio Satellite Navi Watch

- PAT-1GP first generation version introduced in 1999
- PAT-2GP second generation version introduced last year
- More compact and lighter
- Rechargable lithium-ion battery
- PC interface
- $499.95 (U.S.)

FCC E-911 Requirements

- FCC issued a Report and Order in October 1996 requiring U.S. network operators to implement an E-911 location capability by October 2001
- Phase I: Pass caller's phone number, cell-site, and cell-sector location information to public safety answering point (PSAP) by April 1998
- Phase II: Provide caller's location (latitude and longitude) to appropriate PSAP by October 2001 – automatic location identification (ALI)
- 2 major solution technologies: network-based and handset-based

Networked-based Location Technologies

– provides the location of wireless 911 callers using hardware and/or software in the wireless network and/or another fixed infrastructure

– does not require the use of special location determining hardware and/or software in the caller’s portable or mobile phone

– e.g., time-difference of arrival (TDOA), angle of arrival (AOA), hybrid systems, RF “fingerprinting”

Handset-based Location Technologies

– provides the location of wireless 911 callers using special location-determining hardware and/or software in the caller's portable or mobile phone

– may employ additional location-determining hardware and/or software in the wireless network and/or another fixed infrastructure

– e.g., GPS, Loran-C

– GPS: standalone and network-assisted (e.g. SnapTrack)

Phase II Accuracy Standards

- For network-based solutions: 100 metres for 67% of calls; 300 meters for 95% of calls
- For handset-based solutions: 50 metres for 67% of calls; 150 metres for 95% of calls

GPS-capable Handsets

- First sets introduced in 1999
- Several manufacturers currently selling GPS-equipped handsets, mostly in Europe (GSM)
- SiRF Technology recently signed major contracts with both Nokia and Ericsson

The Future of GPS Technology

- Further miniaturization of the technology
- Integration of GPS receivers into PDAs, cameras, sports equipment, etc., etc.
- Pet, child, and disabled tracking systems and services
- Other location-based services such as L-commerce
- Network-assisted GPS (permits weaker signal use)
- Bluetooth (short range RF) connectivity between GPS receivers and other Bluetooth-equipped devices (GPS + Bluetooth = positioning inside buildings?)
- New GPS signals; higher power signals
- GPS + GLONASS + Galileo

GPS R&D at Canadian Universities

- Main research labs:
  - Geodetic Research Laboratory, Dept. of Geodesy and Geomatics Engineering, University of New Brunswick (Langley, Santos, Dare)
  - Satellite-based Positioning and Navigation Group, Dept. of Geomatics Engineering, The University of Calgary (Lachapelle, Cannon)
  - Equipe GPS, Centre de Recherche en Géomatique, Université Laval (Santerre)

University GPS R&D Themes

- Physical and mathematical modelling of GPS observables (both functional and stochastic models)
- Development of new techniques and procedures for GPS positioning and navigation and the enhancement of existing techniques
- Assessment of accuracy and integrity of positional information

- Modelling the neutral-atmosphere propagation effects in radiometric space techniques
- Improved modelling of data from the Western Canada Deformation Array
- Development of a low-cost GPS-based vehicle tracking system
- Automatic daily assessment of the GPS broadcast ephemerides
- Automatic daily assessment of WAAS corrections and WAAS performance in eastern Canada
- Development of precise point positioning algorithms and software

University of New Brunswick, cont'd.

- Geometric tracking of GPS-equipped low earth orbiters
- Automated cycle slip correction
- Stochastic modelling of GPS observations
- Improvement of precise and reliable kinematic GPS positioning in real time
- Optimal techniques for GPS ambiguity resolution
- Development of multipath mitigation techniques
- Ionospheric effects on Galileo
- Establishment of reference sites and control networks
- GPS equipment and site testing

The University of Calgary

- Availability, reliability and accuracy of GPS/Galileo
- Estimation of oscillator stability in the time domain using GPS
- GPS/INS integration
- Use of multiple GPS antennas/receivers for code and carrier phase multipath mitigation
- Vehicular navigation in urban canyons and under forestry canopy
- Use of multiple reference stations for GPS carrier-phase based positioning
- Centimetre-level relative positioning of distributed moving platforms

The University of Calgary, cont'd.

- Availability and reliability of GPS augmented with other satellite systems and onboard sensors
- Use of GPS/INS for aircraft positioning
- Use of combined GPS and GLONASS for heading and pitch determination
- Effect of the ionosphere on GPS in auroral regions
- Effect of ice loading on GPS antennas
- Augmentation of GPS with pseudolites
- GPS-based attitude determination using a multi-antenna approach
- Application of GPS and GIS technologies to precision farming

Université Laval

- Improvement of kinematic OTF-GPS positioning over long distances
- Integration of GPS/GLONASS satellite positioning systems
- Improvement of GPS ambiguity resolution using height constraint for bathymetric surveys
- Simulations of attitude determination for RADARSAT-I using GPS
- Direct determination of angular velocity using GPS
- A combined method for GPS ambiguity resolution with single frequency receivers
- Development of a GPS-based system for the support of ship berthing operations

Université Laval, cont'd.

- Use of GPS for bridge deformation monitoring
- Impact of antenna configuration on GPS attitude determination
- Development of a telescopic mast for a GPS antenna
- Modelling ionospheric effects for ambiguity resolution
- Use of GPS in large engineering works
- Use of GPS for precision agriculture
- Combined use of GPS and RADARSAT imagery for deformation monitoring
- Use of GPS in sport

Back-up slides

Garmin NavTalk

- Garmin Corporation, Olathe, KS
- NavTalk Pilot: first GPS-equipped cellular telephone (1999)
- Advanced Mobile Phone System
- Moving-map display
- First Assist™ one-touch emergency service
- Standard version (NavTalk) also available
- NavTalk II GSM phone (4th Q, 2001)

Tendler Cellular FoneFinder

- GPS receiver add-on to conventional cellular phone
- Emergency button
- Position information sent in synthesized voice announcement

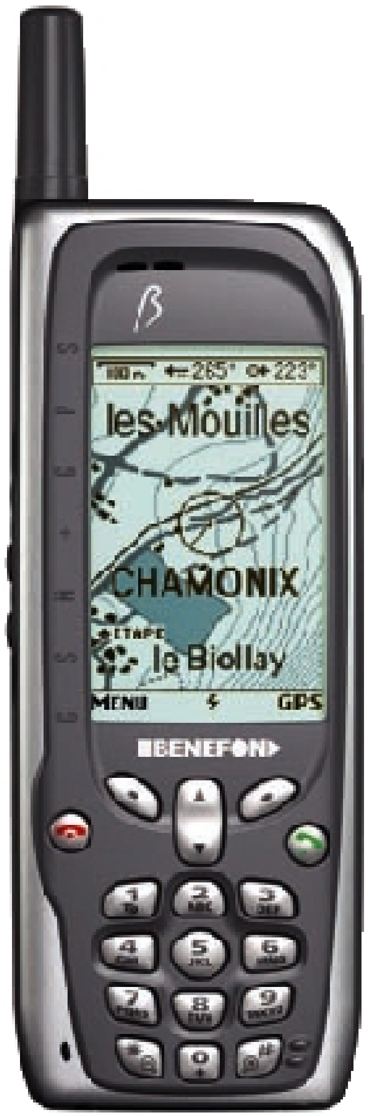
Airbiquity GPS Accessory

- Airbiguity Inc., Bainbridge Island, WA
- Adds GPS capability to existing Nokia 5100, 6100, and 7100 series phones
- 12-channel, SiRF chip set based Axiom GPS receiver built into phone battery pack
- Single button transmission of position
- Data port for Palm OS PDAs

Benefon Track GSM+GPS Phone

- Benefon Oyj, Salo, Finland
- Professional telematics phone
- GSM phone + GPS
- 12-channel (all-in-view) GPS receiver
- Flip-up GPS antenna
- Short Message Service
- Mobile Phone Telematics Protocol
- Emergency dialing

Benefon Esc! Personal Navigation Phone (1)



- Benefon Oyj, Salo, Finland
- Personal navigation phone
- GSM phone + GPS
- 12-channel (all-in-view) GPS receiver
- Flip-up GPS antenna
- 100 x 160 pixel screen
- Map display
- External antenna and NMEA connectors

Benefon Esc! Personal Navigation Phone (2)

- Personal organizer
- E-mail and Web access
- Short Message Service
- Mobile Phone Telematics Protocol
- Mobile Map Service Protocol

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