The Global Positioning System: Past, Present, and Future

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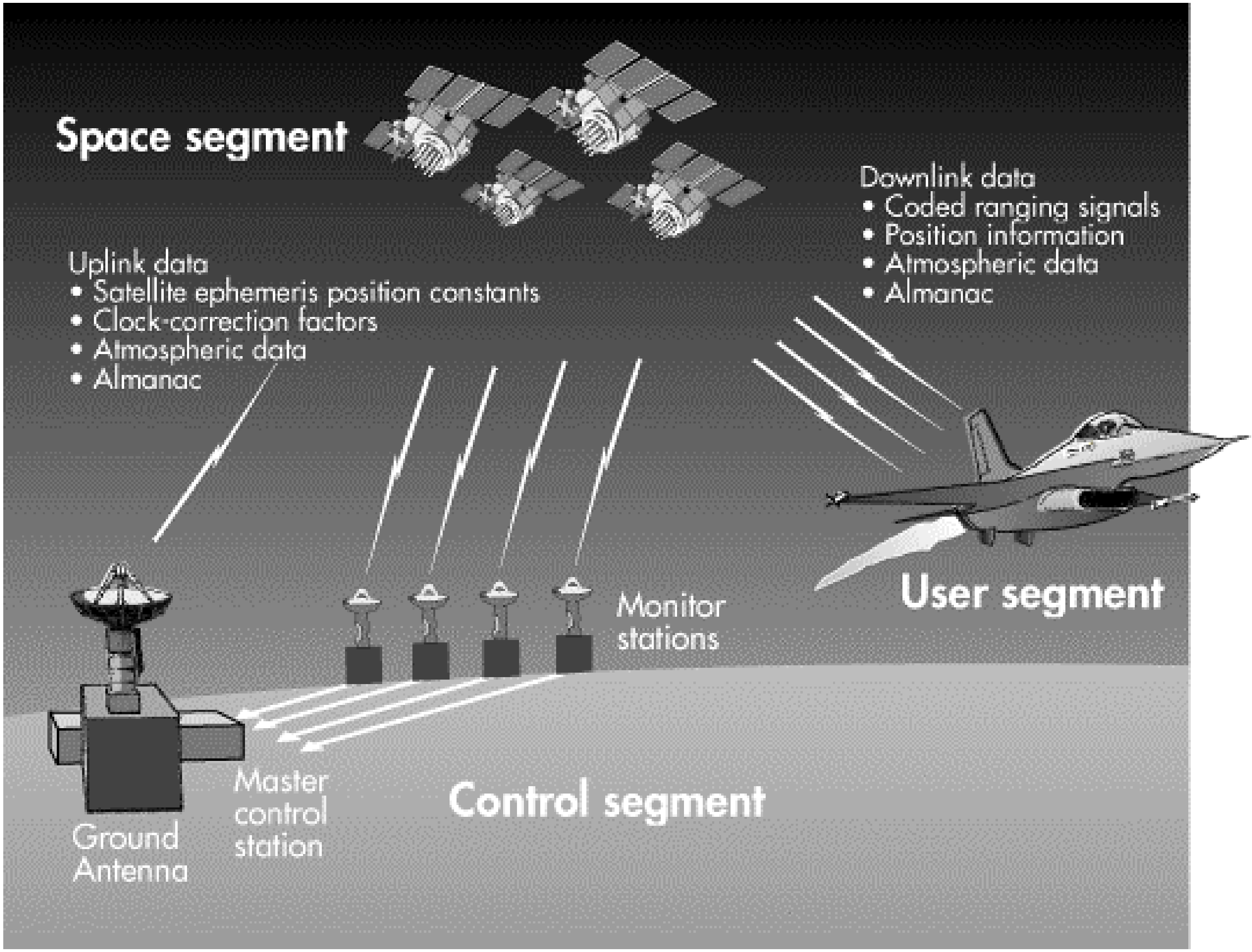
19 Jun. 01

Outline

- Introduction to GPS
- Current status
- Advances in receiver technology
- GPS capabilities
- Uses
- GPS for public safety
- E-911 requirements
- GPS and E-911
- GPS-equipped phones
- UNB GPS R&D strengths
- The future

GPS Segments



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GPS Constellation

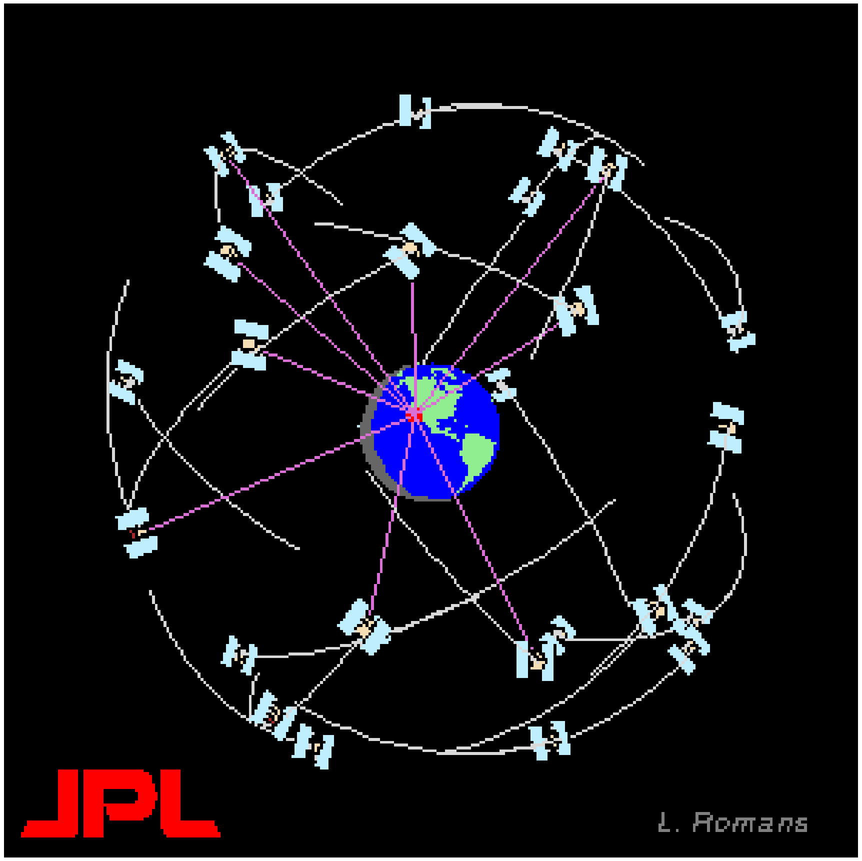
Altitude: 10,900 nmi

Orbital Period: 12 hrs (semi-synchronous)

Orbital Plane: 55 degrees

Number of Planes: 6

Vehicles per plane: 4-5



Constellation size: >24 satellites (currently 28)

GPS Satellites

Generations of Satellites

Block I	Prototype (test) satellites. 10 launched between 1978 and 1985. All retired.
Block II	Initial operational satellites. 9 launched between 1989 and 1990. 5 still functioning.
Block IIA	Slightly modified Block IIs. 19 launched between 1990 and 1997. 18 still functioning.
Block IIR	Replenishment satellites. 6 orbited to date. First in 1997. C/A code on L2 plus higher power on last 12 satellites launched from 2003 onwards.
Block IIF	Follow-on satellites. New civil signal at 1176.45 MHz. First launch expected in 2005.
Block III	Conceptual.

Satellite Launches

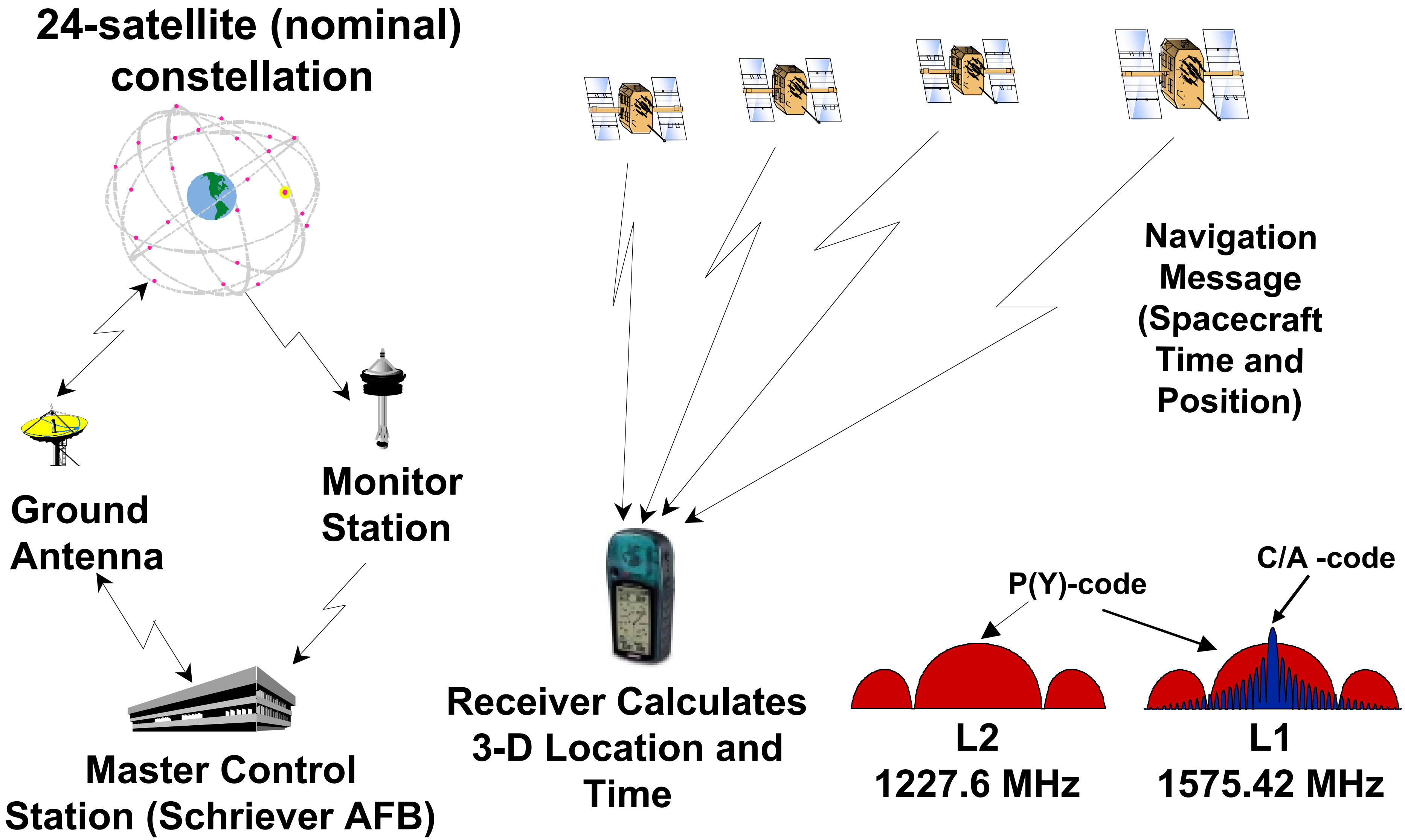
Recent launches:

- IIR-6, SVN 41, PRN 14
  10 November 2000
- IIR-7, SVN 54, PRN 18
  30 January 2001

Next launch:

- IIR-8
  6 March 2002

GPS Signals



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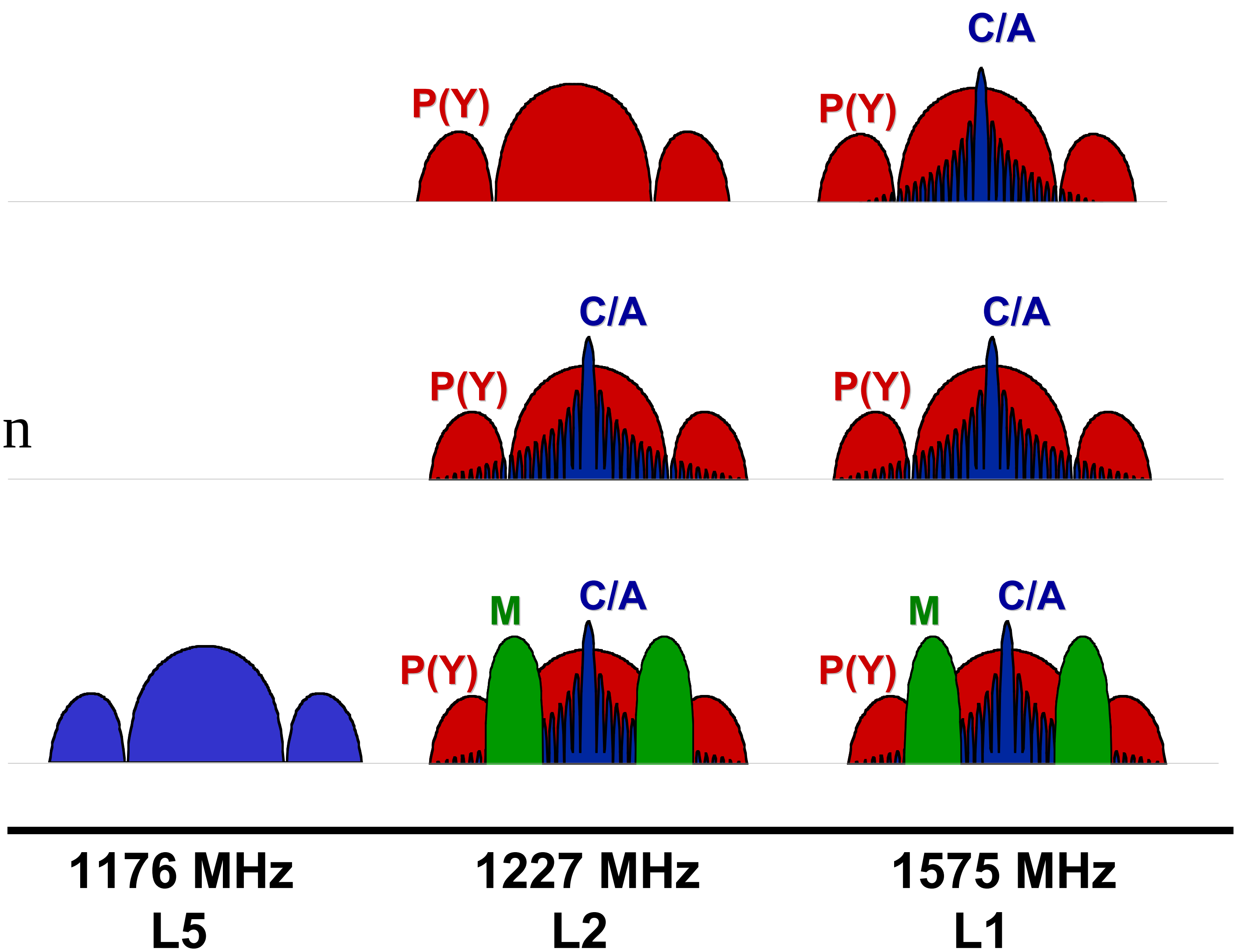
Signal Modernization

Present Signal

Civil Non-Aviation Signal (>2003)

Civil Aviation & New Military Signals (>2005)



GPS History

- 1973 - Consolidation of several U.S. DoD developmental programs into the Navstar Global Positioning System
- 1978 - First prototype satellites launched
- 1983 - Korean Airlines Flight 007 shot down. President Reagan reafirms U.S. policy on civil use of GPS
- 1989 - First operational satellites launched
- 1993 - Initial Operational Capability (24 satellites)
- 1995 - Full Operational Capability
- 2000 - Selective Availability turned off

GPS Benefits

- 24-hour, all weather, worldwide service
- Extremely accurate, three-dimensional location information (providing latitude, longitude, and altitude)
- Extremely accurate velocity information
- Precise timing services
- A worldwide common spatial reference frame (WGS 84) that is easily converted to any local frame, e.g., NAD 83 (CSRS)
- Continuous real-time information
- Accessibility to an unlimited number of worldwide users

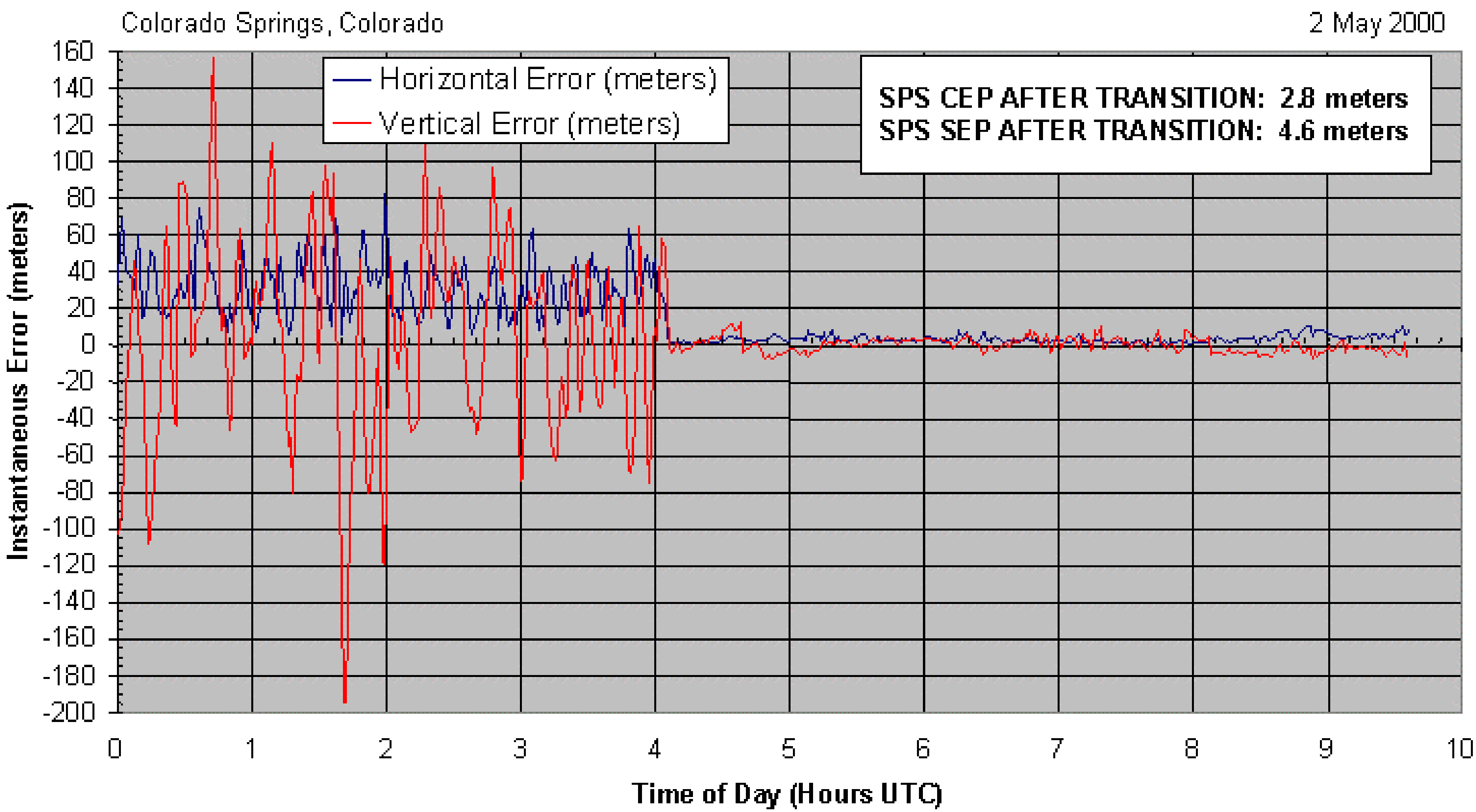
Positioning Accuracy

Accuracy	Method	Relative Cost
10 - 30 m	Single receiver	$ - $$
1 - 10 m	Differential code (Simple receiver)	$ - $$
10 cm - 1 m	Differential code	$$
1 - 10 cm	Differential phase (Real-time kinematic)	$$$$
2 - 5 mm	Differential phase (single frequency)	$$
2 - 5 mm	Differential phase (dual frequency)	$$$$$

Differential GPS

- Increases stand-alone GPS receiver accuracy
- Several commercial and public broadcast systems in use or under development:
  - Coast Guard LF beacons (public)
  - FM sub-carrier (commercial)
  - Satellite L-band (commercial)
  - Wide Area Augmentation System (public)
  - Canada-wide DGPS Service (public)
- Private systems also used

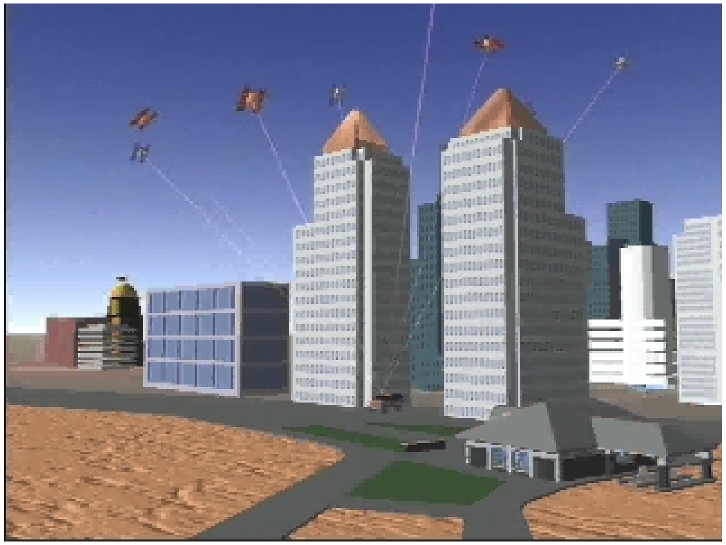
Selective Availability Switched Off



GPS Difficulties

- GPS signals relatively weak (actually buried in background noise)
- Signals cannot 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

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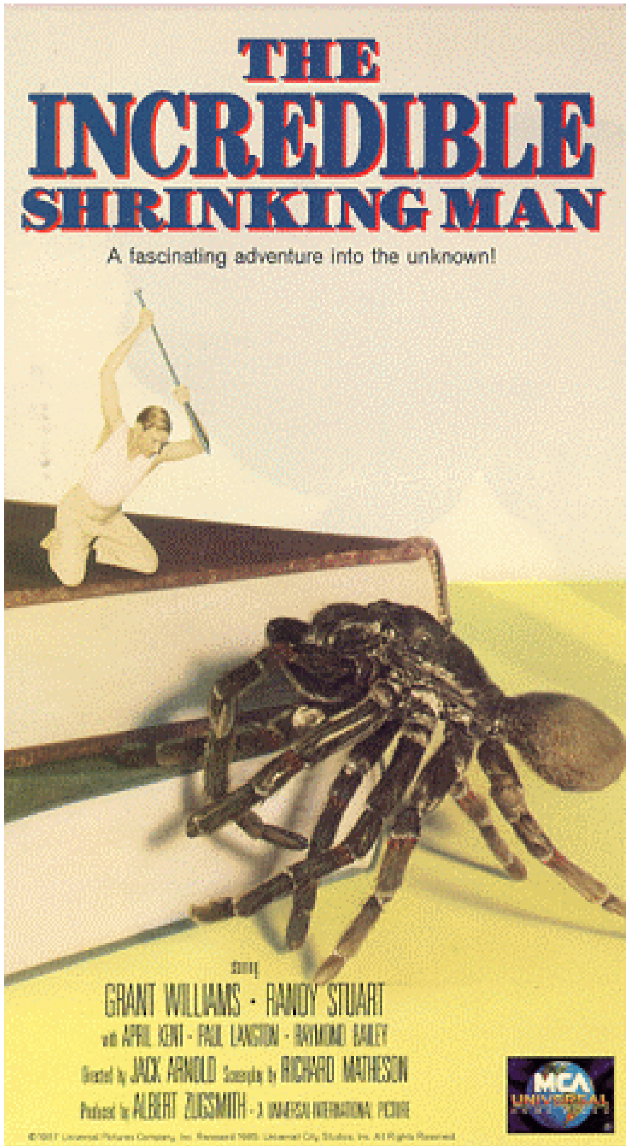
The Incredible Shrinking GPS Receiver

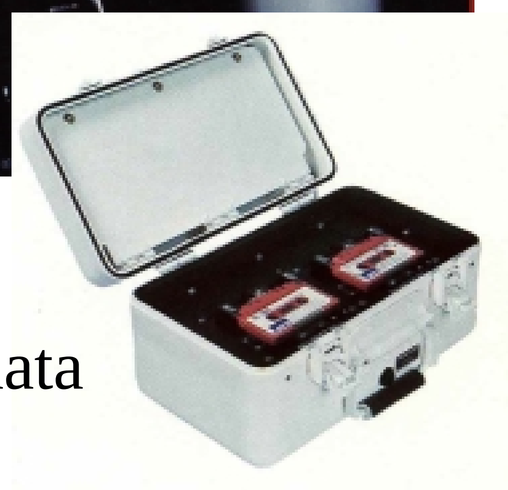


- First commercially available GPS receivers, circa 1980, consisted of two 19-inch racks of electronics
- In 1982, first “portable” receiver introduced; weighed 25 kg and consumed 110 watts of power
- First large handheld receivers introduced in 1988
- 1993: multi-chip module prototype
- 1999: GPS watch

Macrometer V-1000

- Initial development at MIT; introduced 1982
- L1 codeless receiver + time signal receiver
- 73 kg receiver + 18 kg antenna

Texas Instruments TI4100

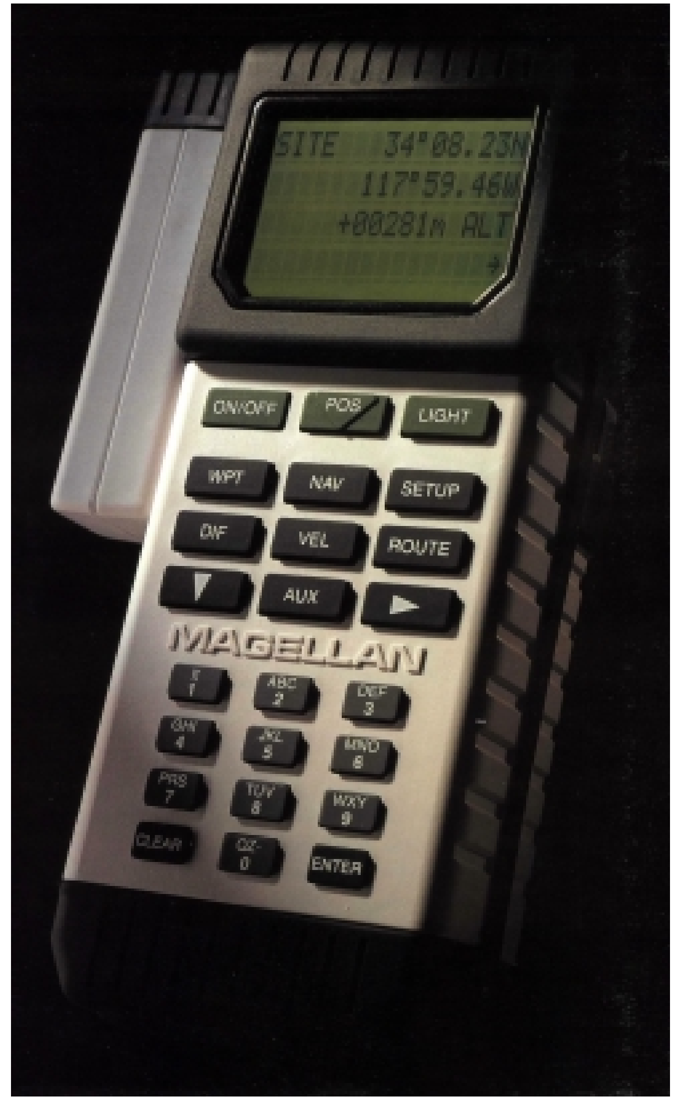


- First “compact” civil GPS receiver
- Introduced 1982
- Dual frequency, C/A- and P-code
- Single channel, multiplexing receiver
- 25 kg, 110 watts!
- Doubled as hand warmer in winter

- Separate dual cassette unit for data recording

Magellan NAV 1000

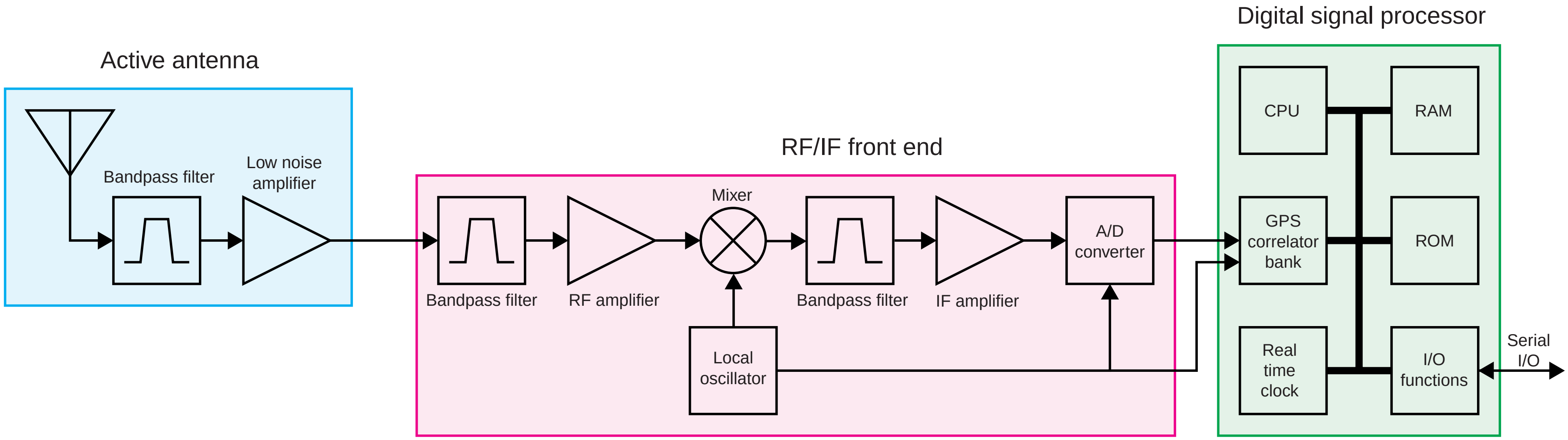
- Introduced in 1988
- Single channel, sequencing L1 C/A-code handheld receiver
- Tracked best 4 satellites
- Initially for marine market; military and land user versions subsequently produced
- Widely used in the Gulf War



Trimble Navigation Trimpack

- Introduced in 1988
- 2-channel, sequencing L1 C/A-code handheld receiver
- Tracked up to 8 satellites
- Widely used during the Gulf War

“Two Chip” GPS Receiver



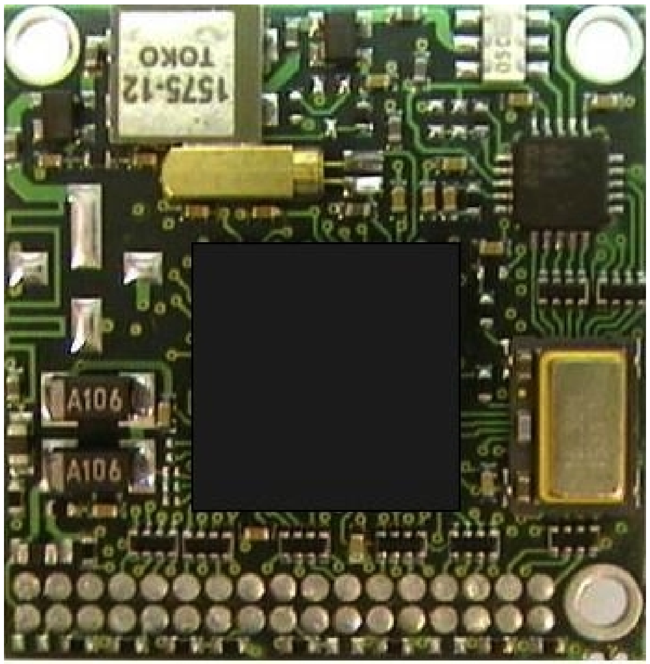
AxiomNavigation Swift B1 OEM Receiver

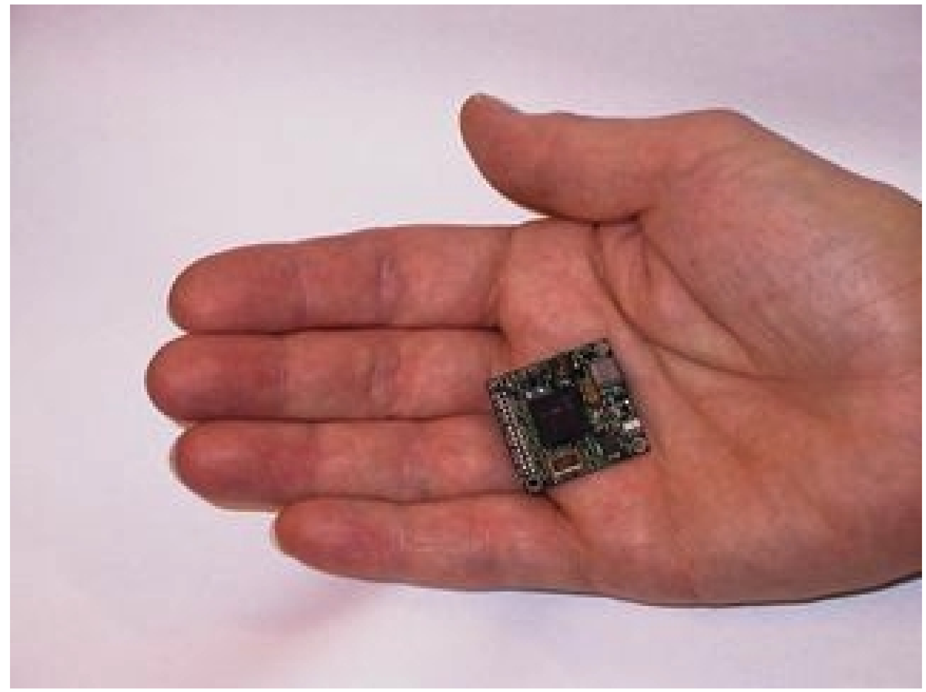
- OEM module
- Based on SiRF 2nd generation chip set

iTrax02 GPS Receiver Module

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

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

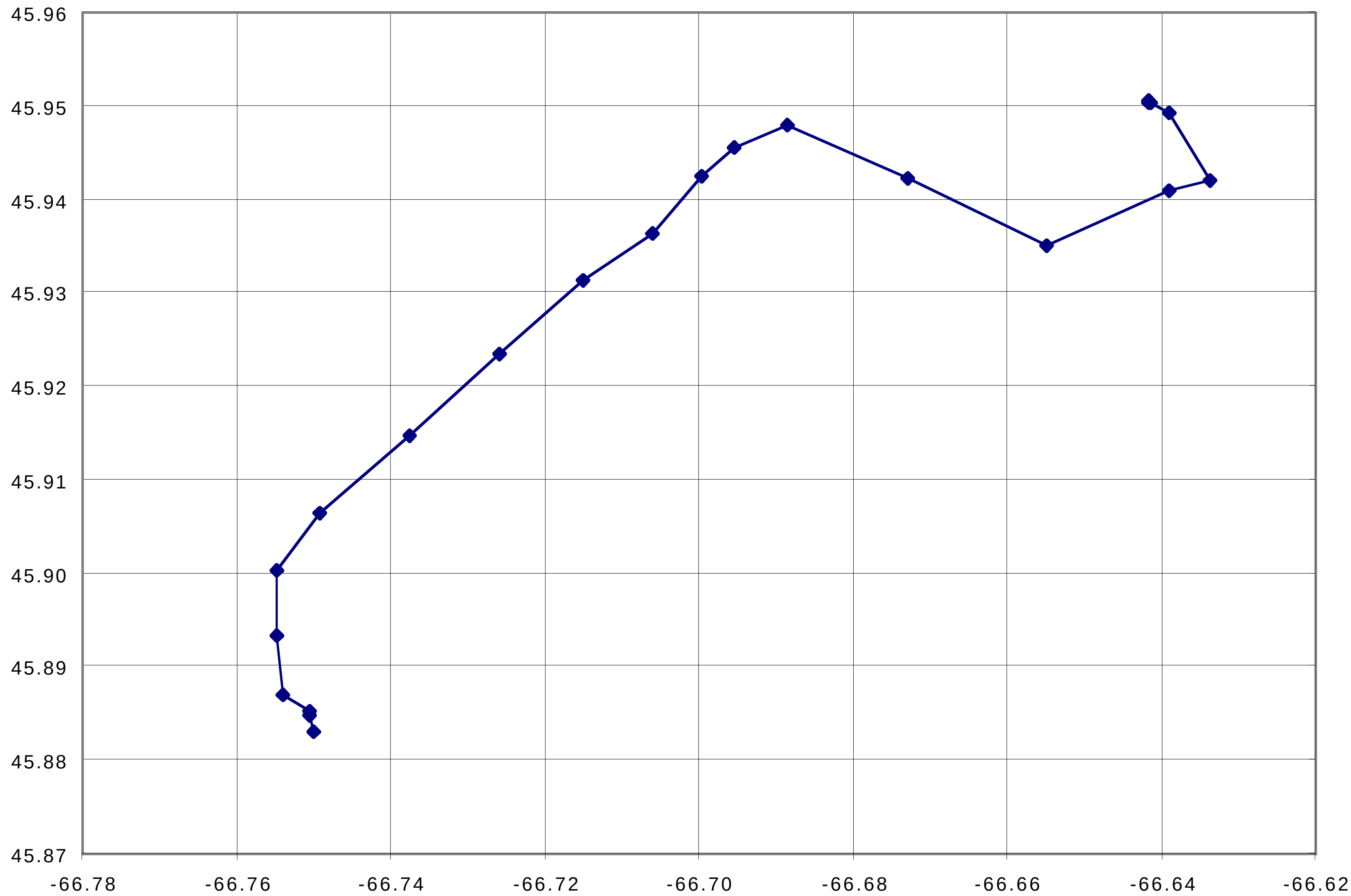




Casio Satellite Navi Watch

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

Starlite Village -> UNB



UNB's 1983 Forecast

THE FUTURE OF GEODETIC NETWORKS

PETR VANÍČEK, DAVID E. WELLS, ADAM CHRZANOWSKI,
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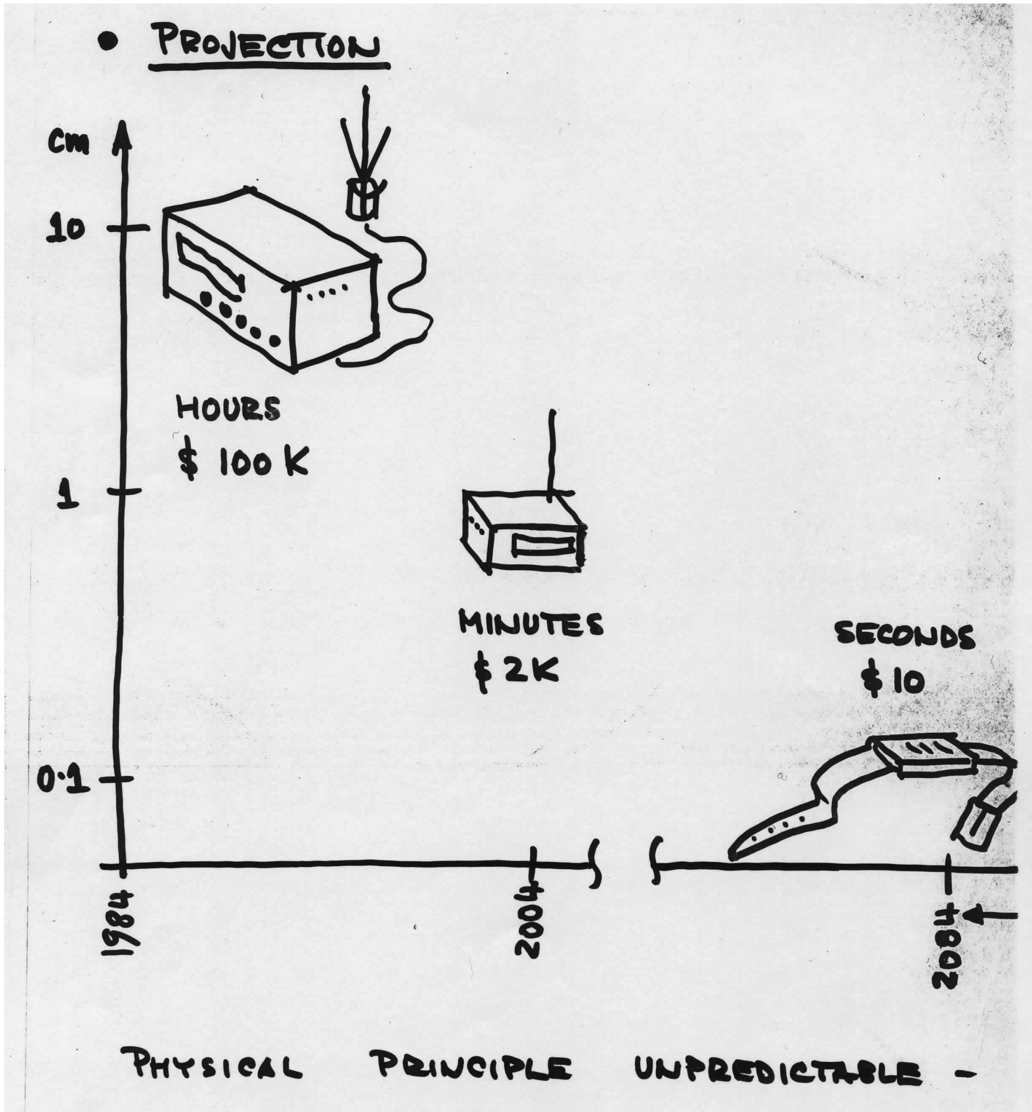
JOHN D. MCLAUGHLIN, BRADFORD G. NICKERSON

Our appraisal of the future of geodetic networks is based on the axiom that one of the ultimate goals of geodesy is to make accurate positioning as readily available to everyone as accurate timing is today. Thus sometime in the distant future we forsee people walking around with "wrist locators" costing less than ten 1983 dollars that will provide instantaneous positions to, say, 1 mm accuracy. More immediately, i.e., within the next 25 years, there are likely to be available highly portable locators costing a few thousand 1983 dollars which will deliver almost instantaneous positions good to 1 or 2 cm.

Are We There Yet?



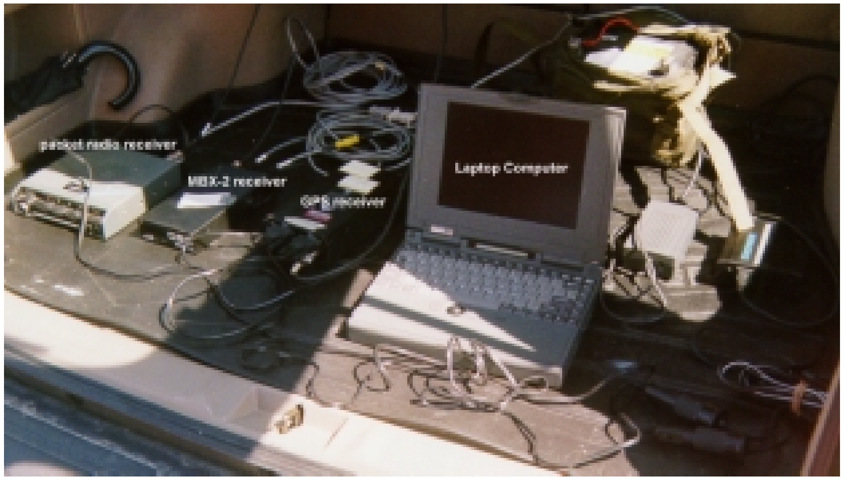
GPS Benefits to Public Safety

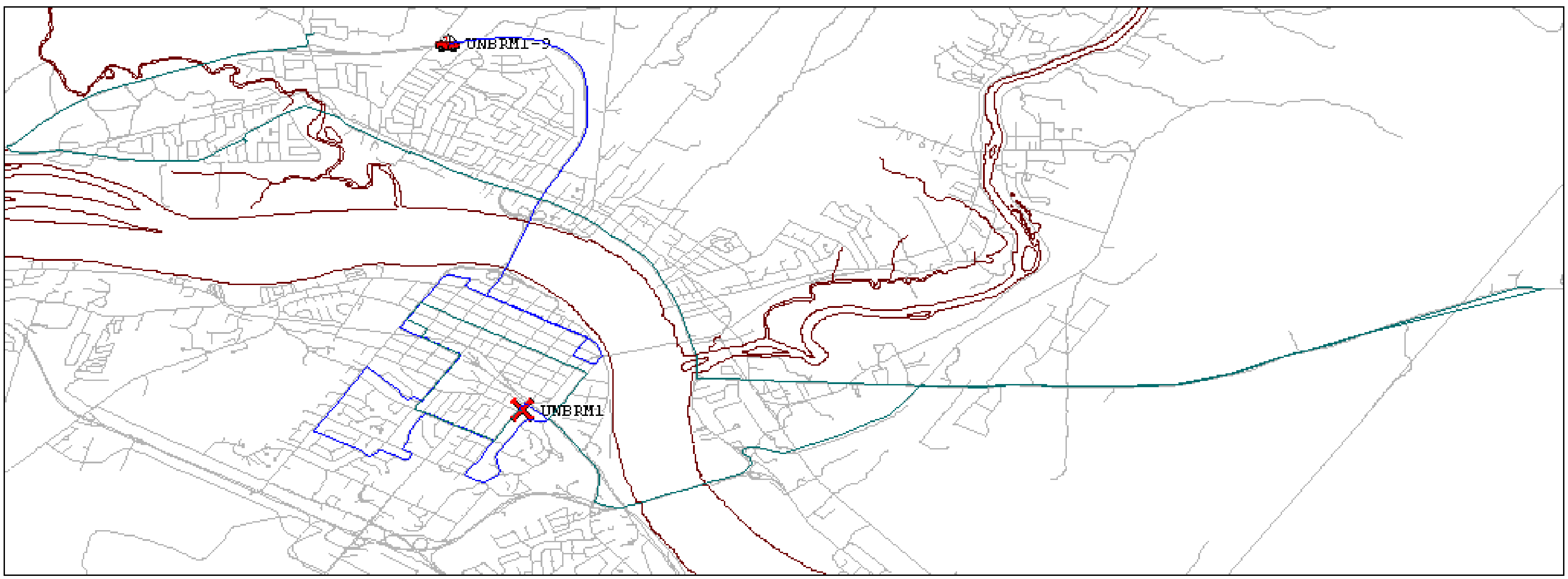
- Rapid response and dispatch of emergency services
- Decreased response time to exact locations
- Search and rescue
- Emergency vehicle tracking/reporting

GPS Tracking Systems

- Many commercial products on the market
- Systems tailored to trucking, taxi, public service, and emergency vehicle fleets
- Variety of communication systems and protocols in use:
  - Terrestrial VHF and UHF dedicated links
  - "Piggy-backing" over existing communication channels
  - Cellular telephone network
  - Satellite links

UNB's "Home Brew" GPS Tracking System





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

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

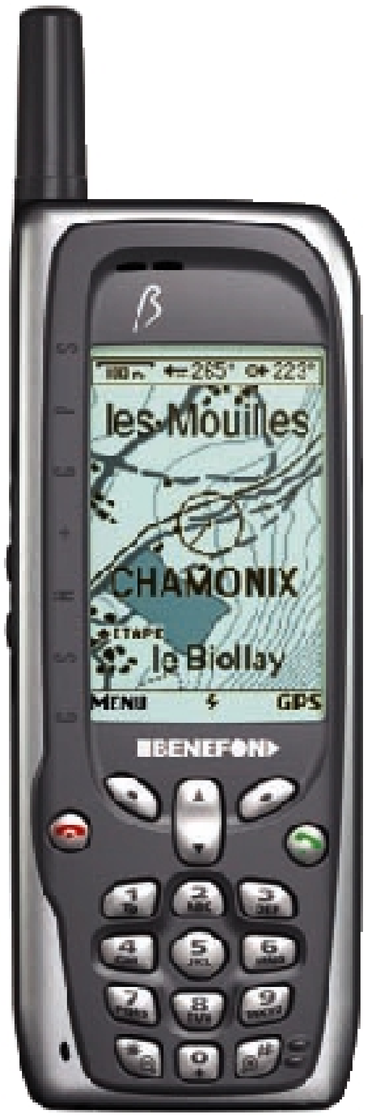
Airbiquity GPS Accessory

- Airbiquity 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

UNB's Strengths in GPS R&D

- 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

Geodetic Research Laboratory - GPS

- Cycle slip determination.
- Estimation of integer ambiguities.
- Receiver testing.
- Precise orbit determination of LEO satellites.
- Long-baseline kinematic GPS.
- Analysis of Western Canada Deformation Array data.
- Analysis of WAAS corrections.

Geodetic Research Laboratory - GPS

- Atmospheric modelling.
- Orbital accuracy studies.
- Optimal design of networks.
- GPS+IKONOS for archaeological studies.
- Subsidence studies at Salto Caxias Dam, Brazil.
- Velocity field estimation of the Brazilian portion of the South American tectonic plate.

The Future of GPS Technology

- Further miniaturization of the technology (smaller and smaller)
- Integration of GPS receivers into PDAs, cameras, sports equipment, etc., etc.
- Pet, child, and disabled tracking systems and services
- 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

UNB will be there!

Further Information

- http://www.fcc.gov/e911/
- http://www.garmin.com/aboutGPS/
- http://www.gpsworld.com/
- http://www.unb.ca/GGE/

Acknowledgements

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- Axiom Navigation
- iTrax
- Garmin