

From Sputnik to APRS

The History of GPS

A 35-Minute Journey Through Navigation History

Paul J. Wilkinson, K6IG

APRS • GPS • Emergency Communications



Today's Journey

Part 1 The Cold War Spark (1957–1964)

Part 2 U.S. Navy: LORAN, Atomic Clocks & Transit (1950s–1970s)

Part 3 NAVSTAR GPS — Birth of the Modern System (1973–1995)

Part 4 GPS Goes Civilian: Coast Guard, FAA & Global Expansion (1991–2010s)

Part 5 APRS — Ham Radio Meets GPS (1992–Today)

Part 6 Live Demo & Q&A

The Spark: Sputnik — October 4, 1957

- Soviets launch Earth's first artificial satellite
- Weighed 184 lbs — about the size of a beach ball
- Transmitted a simple radio beep on 20 & 40 MHz
- U.S. public: shock. Pentagon: alarm.
- Two physicists at Johns Hopkins University Applied Physics Laboratory — William Guier & George Weiffenbach — track Sputnik using Doppler shift
- Key insight: if you know your position, you can find the satellite... and vice versa!



October 4, 1957

The beep that changed navigation forever

**96-min orbit
1,440 beeps/day**

Before GPS: Navy Navigation & Timing Heritage

LORAN-C (1957–2010)

- Long Range Navigation — 100 kHz hyperbolic system
- Accuracy: 250–450 m over open ocean
- U.S. Coast Guard operated the transmitter chains
- Used phase differences of LF pulses between master/slave stations
- Covered North Atlantic, Pacific, continental US
- Backbone of Navy & Coast Guard navigation until GPS
- Shut down by DHS January 8, 2010 — GPS had replaced it

Atomic Clocks & NBS

- NBS (now NIST) — National Bureau of Standards, Boulder CO
- NBS-1 cesium beam clock (1952): first atomic time standard
- Rubidium oscillators: compact, $\sim 10^{-11}$ stability — ideal for orbit
- Naval Research Laboratory (NRL) TIMATION program flew rubidium clocks in orbit, 1967–1974
- Proved atomic clocks could survive launch and function in space
- GPS satellites carry cesium & rubidium clocks accurate to 20–30 ns
- 1 nanosecond timing error = ~ 30 cm position error — clocks ARE GPS

TRANSIT System (1960–1996)

- Johns Hopkins Univ. Applied Physics Lab — developed 1958
- 5–6 satellites in polar orbits — Doppler-shift ranging
- Primary customer: Navy Polaris submarines
- 150 & 400 MHz signals; fix accuracy ~ 200 m
- Wait up to 90 min between fixes — stationary receivers only
- Civilian release 1967; served maritime users into 1990s
- Its limitations directly drove every NAVSTAR GPS design choice

Pentagon Power Struggle: One System to Rule Them All

- **1966** USAF Project 621B — satellite nav study begins
- **1967** Navy TIMATION program — atomic clocks in orbit
- **1972** Army SECOR — ranging experiments
- **1973** DoD mandates ONE unified system — NAVSTAR GPS
- **1973** Col. Bradford Parkinson named program director

"The services were going to cooperate whether they liked it or not." — Parkinson, 2010

The Fathers of GPS



Col. Bradford Parkinson

USAF

"Father of GPS"

- Led the NAVSTAR GPS program from 1973
- Designed the 18-satellite minimum constellation
- Insisted on civilian signal from day one
- Fought for open, free access to GPS signals
- National Medal of Technology, 2004



Roger Easton

NRL — Naval Research Lab

Transit & TIMATION Pioneer

- Developed atomic clock timing concepts for orbit
- TIMATION satellites tested precision clocks
- Core timing tech adopted directly into GPS
- National Medal of Technology, 2004 (with Parkinson)
- Often called co-father of GPS

NAVSTAR GPS Architecture: Three Segments



Space Segment

- 24+ satellites in MEO (20,200 km)
- 6 orbital planes, 4 sats per plane
- 55° inclination ensures global coverage
- Atomic clocks: accurate to 20–30 ns
- Broadcasts on L1 (1575.42 MHz) & L2 (1227.60 MHz)
- Block II-F & III satellites now operational



Control Segment

- Master Control Station: Schriever AFB, CO
- 5 monitor stations worldwide
- Ground antennas upload corrections daily
- Continuously monitors satellite health
- Computes ephemeris & clock corrections
- Colorado Springs — our backyard!



User Segment

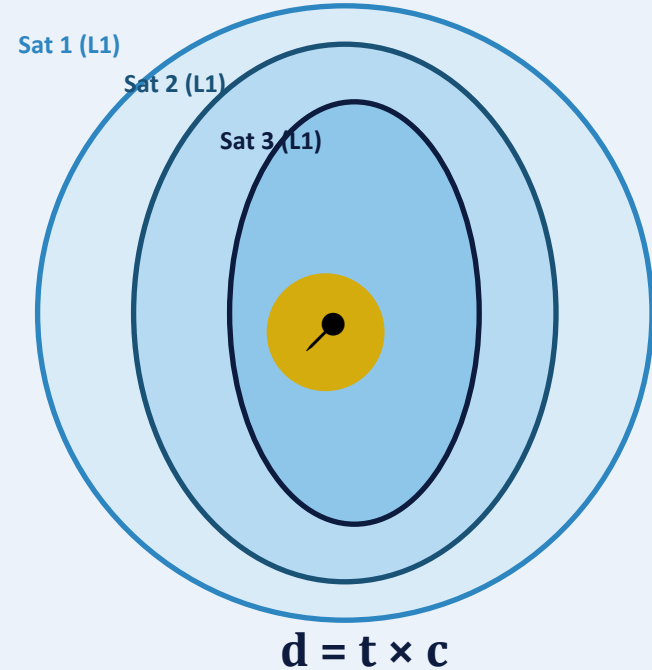
- Any GPS receiver — military or civilian
- Calculates position from 4+ satellites
- Uses pseudorange measurements
- Chipsets cost < \$2 today
- Billions of devices worldwide
- Includes your APRS trackers!

How GPS Actually Works: Trilateration

The Math Made Simple

- Each satellite broadcasts its position & timestamp
- Receiver measures signal travel time \times speed of light = distance (pseudorange)
- One satellite \rightarrow you're on a sphere
- Two satellites \rightarrow intersection of two spheres = a circle
- Three satellites \rightarrow two possible points (one invalid)
- Four satellites \rightarrow resolves clock error in receiver
- More satellites = better accuracy
- Typical civilian accuracy: 3–5 meters

Signal Travel Time



distance = time \times speed of light

Building the Constellation: 1978–1995

Feb 1978

First NAVSTAR satellite launched — Block I series begins

1983

KAL Flight 007 shot down — Reagan opens GPS to civilians

1985

10 Block I satellites operational — limited testing

1989

Block II production satellites begin launching

1991

Gulf War — GPS proves itself in combat, 16 operational sats

1993

Initial Operational Capability (IOC) — 24 satellites

Apr 1995

Full Operational Capability (FOC) declared — GPS is LIVE

✓ COMPLETE

Selective Availability: When the DoD Lied to You

What Was SA?

- DoD intentionally degraded civilian GPS signal
- Added clock dithering — fake timing errors
- Civilian accuracy deliberately reduced to ~100 m
- Military (P-code/Y-code) kept at ~10–20 m
- Rationale: prevent enemies from using GPS precisely
- Result: civilians frustrated, workarounds developed
- Differential GPS (DGPS) became popular to compensate

The End of SA — May 1, 2000



- Clinton orders SA turned off midnight May 1, 2000
- Instant 20× improvement in civilian accuracy
- DoD concluded commercial competition made it moot
- WAAS & modern receivers achieve sub-1-meter
- SA officially eliminated by law in 2007
- No going back — the world changed overnight

GPS Signal Architecture: What's in the Air

L1

1575.42 MHz

Codes: C/A + P(Y)

Primary civilian + military

L2

1227.60 MHz

Codes: P(Y) + L2C

Military + modern civilian receivers

L5

1176.45 MHz

Codes: Safety-of-Life signal

Aviation, search & rescue, high precision

C/A = Coarse Acquisition • P(Y) = Encrypted Precision • All signals CDMA spread-spectrum

Desert Storm: GPS Proves Its Worth (1991)

Operation Desert Storm — GPS Combat Debut

- Only 16 GPS satellites operational — incomplete constellation
- Military issued commercial Trimble receivers to troops (too few PLGRs)
- GPS-guided smart bombs transformed precision strike capability
- Armor units navigated featureless Iraqi desert via GPS
- Friendly fire incidents dramatically reduced
- PLGR (Precision Lightweight GPS Receiver) — troops called them "Pluggers"
- "Left hook" flanking maneuver: GPS-guided 100-hour ground war
- DoD immediately accelerated constellation completion after the war

OIF/OEF: Blue Force Tracker

- BFT-1 fielded in Iraq & Afghanistan post-2001
- Combined GPS position + INMARSAT satellite data link
- Displayed all friendly unit icons on digital map — real-time
- Commander Situational Awareness (SA) transformed at every echelon
- BFT-2 upgraded to Iridium + MUOS for lower latency
- Integration with Force XXI Battle Command, Brigade & Below (FBCB2)
- Blue Force = own troops • Red icons = known enemy (DAGR/CPOF)
- Direct evolution: from Plugger (position only) → BFT (networked SA)

GPS Goes Civilian: The Commercial Revolution

1996–2000 · Early Adopters

- Garmin & Magellan handheld GPS
- Marine chartplotters
- Aviation FMS integration
- Early vehicle navigation (\$2,000!)

2000–2007 · SA Off + WAAS

- Sub-5m civilian accuracy
- Automotive OEM GPS (OnStar)
- First GPS phones (early 2000s)
- Geocaching born May 2000!

2008–2015 · Smartphone Era

- iPhone 3G — GPS standard
- Google Maps + GPS = revolution
- Waze, Uber, DoorDash possible
- GPS chip cost < \$2 USD

2016–Now · Precision GNSS

- L5 signal / dual-frequency phones
- Sub-meter RTK for consumer use
- Autonomous vehicles
- Global multi-constellation GNSS

Coast Guard & FAA: GPS in Safety-of-Life Roles

📍 U.S. Coast Guard — Maritime DGPS

- Coast Guard ran LORAN-C chains from 1957 onward
- 1989: USCG begins Differential GPS (DGPS) research
- Broadcast GPS corrections from coastal beacon stations
- Used existing LORAN transmitter sites — smart infrastructure reuse
- Nationwide DGPS (NDGPS): 85 beacon sites, ~1–3 m accuracy
- Covered US coasts, Great Lakes, and major inland waterways
- 2015: FAA assumed NDGPS operations — USCG mission complete
- LORAN-C decommissioned Jan 8, 2010 — GPS had proved reliable

✈️📍 FAA — Wide Area Augmentation System

- FAA required < 7.6 m vertical accuracy for aviation GPS use
- 1994: WAAS program begins — Stanford Research Intl & Raytheon
- Ground reference stations (WRS) nationwide measure GPS errors
- Wide-Area Master Station (WMS) computes ionospheric corrections
- Corrections broadcast via GEO satellite on GPS L1 (1575.42 MHz)
- 2003: WAAS declared operational — LPV approaches enabled
- LPV = 200-ft decision height; rivals ILS at thousands of airports
- GPS now Primary Means navigation from en-route through approach

GPS Is Not Alone: Global GNSS Systems

US

GPS (USA)

31 active · 3–5 m

L1/L2/L5

FOC 1995

RU

GLONASS (Russia)

24 active · 5–10 m

FDMA L1/L2

FOC 1995

EU

Galileo (EU)

28 active · < 1 m (HAS)

E1/E5/E6

FOC 2023

CN

BeiDou (China)

46 active · < 3 m

B1/B2/B3

Global 2020

IN

NavIC (India)

7 active · < 20 m

L5/S-band

Regional 2018

JP

QZSS (Japan)

4 active · < 1 m (SLAS)

L1/L2/L5

Regional 2018

PART 5

APRS

Automatic Packet Reporting System

Where GPS Meets Ham Radio



Bob Bruninga, WB4APR — Father of APRS



Bob Bruninga WB4APR

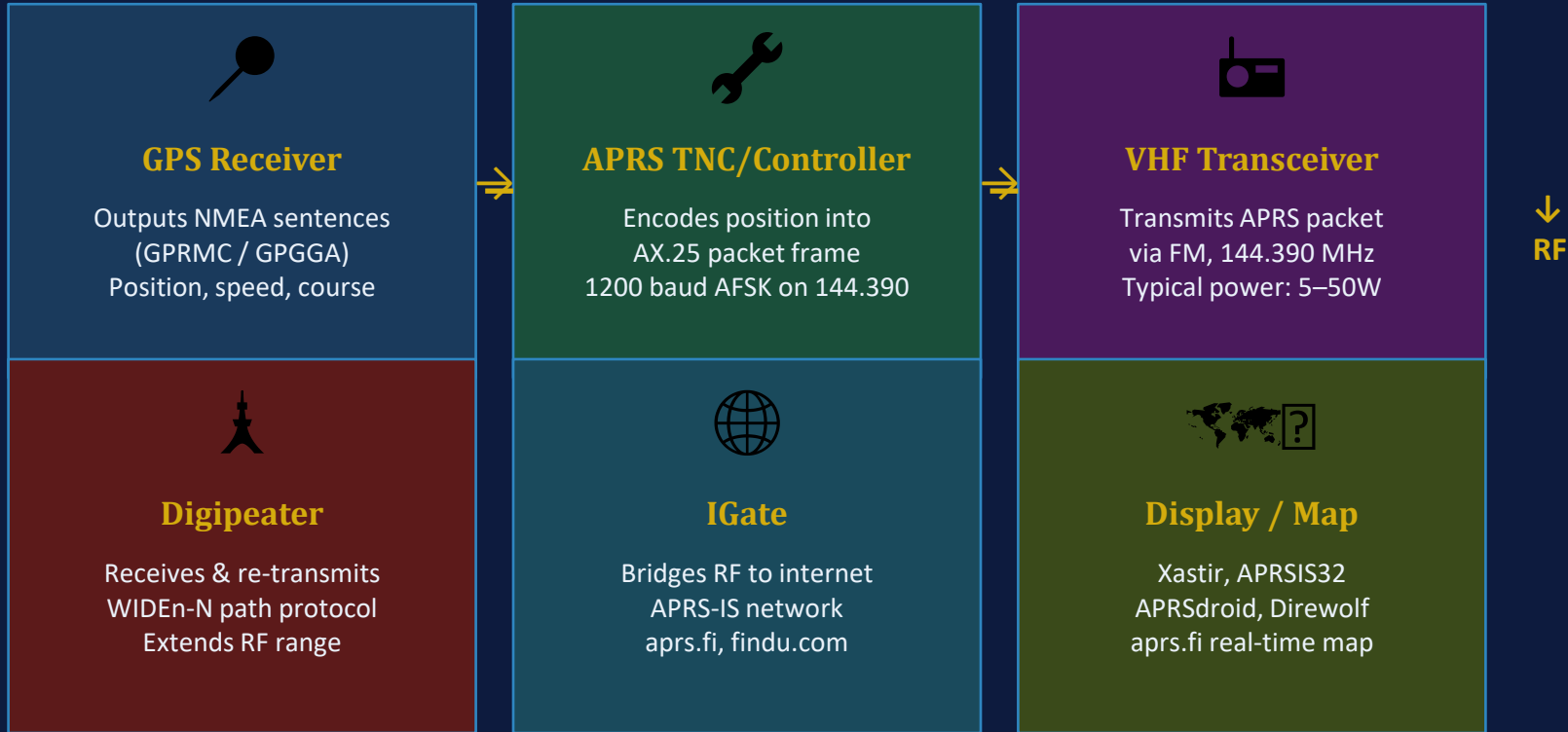
Senior Research Engineer
U.S. Naval Academy, Annapolis MD
1939 – 2022

- 1992: First APRS demonstration at U.S. Army Maneuvers
- Displayed vehicle positions on a Macintosh computer
- Combined VHF packet radio + GPS position data
- Defined the APRS protocol on 144.390 MHz
- Inspired by military battlefield tracking systems
- Operated APRS from the ISS — WB4APR in orbit!
- His legacy: millions of APRS objects worldwide

APRS Timeline

- 1992 — First demo
- 1996 — MacAPRS released
- 2000 — APRSdos public
- 2001 — APRS-IS internet
- 2004 — Xastir, UI-View
- 2013 — APRSdroid
- 2022 — Bob becomes SK

APRS Technical Architecture



Anatomy of an APRS Packet

```
K6IG-9>APRS,WIDE1-1,WIDE2-1:!3851.30N/10452.40W>070/025/A=006240K6IG Mobile en route Megafest
```

Source Call

K6IG-9

Callsign + SSID-9
(mobile)

Destination

APRS

Generic APRS
destination

Digi Path

**WIDE1-1
WIDE2-1**

2-hop
digipeat

Data Type

!

No-messaging
position

Position

**3851.30N
10452.40W**

DDmm.mmN
Lat/Lon

Symbol

> (car)

Icon on map

Course/Speed

070/025

70° at 25 knots

Altitude Field

A=006240 → 6,240 feet MSL

Status/Comment

"K6IG Mobile en route Megafest" → Free text, 43 chars max

The APRS Network: RF + Internet

RF Side

- Primary frequency: 144.390 MHz (North America)
- 144.800 MHz Europe / 145.175 MHz Japan
- FM simplex — 1200 baud AFSK Bell 202
- Narrow deviation: ± 3 kHz
- Typical beacon rate: 1–5 minutes
- Smart beaconing: faster when moving
- Digipeaters: high-site VHF repeaters
- Coverage: ~30–50 miles per hop

↔
IGate

APRS-IS

- APRS Internet Service — global backbone
- TCP port 14580 for filtered connections
- Tier-2 servers federated worldwide
- aprs.fi — live map, 130M+ packets/day
- findu.com — historical tracking
- openaprs.net, aprs.direct
- APRS-IS \neq APRS (internet only = no license needed!)
- IGate bridges RF ↔ Internet both ways

APRS Hardware: What You Need to Get on the Map

All-in-One Trackers

- Mobilinkd TNC + smartphone (APRSdroid)
- Byonics TinyTrak4 — classic favorite
- Argent Data OT3m / T3-Mini
- Kenwood TH-D74A — HT with APRS built in
- Yaesu FT5DR — System Fusion + APRS

Radio + TNC Combos

- Any VHF FM radio + Mobilinkd TNC3
- Any radio + Signalink + software TNC
- Baofeng UV-5R + \$20 cable + APRSdroid
- DigiRig Mobile — USB sound card TNC
- APRS on a budget: < \$50 possible

Software TNCs

- Direwolf (open source, Pi-friendly)
- AGWPE (Windows soundcard TNC)
- soundmodem (Linux)
- Great for Raspberry Pi APRS nodes
- Full APRS client on Pi Zero W: ~\$15

GPS Sources

- Phone GPS via Bluetooth NMEA
- GlobalSat BU-353 USB puck
- u-blox NEO-6M/7M modules
- Built-in on Kenwood/Yaesu HTs
- Already in every Android phone!

Direwolf: The Open-Source APRS Powerhouse

What Direwolf Does

- Software TNC using soundcard input/output
- Decodes AX.25 APRS packets from audio
- Encodes and transmits APRS beacons
- Built-in APRS digipeater function
- Built-in IGate (Tx and Rx gate)
- Runs on Windows, Linux, macOS, Raspberry Pi
- Supports GPS for position beaconing
- Open source — WB2OSZ (John Langner)

Raspberry Pi APRS Node

```
# One-line Direwolf install
sudo apt install direwolf

# direwolf.conf key settings:
MYCALL K6IG-1
ADEVICE plughw:1,0
CHANNEL 0
PTT GPIO 25
IGSERVER noam.aprs2.net
IGLOGIN K6IG-1 12345
```

- Pi Zero 2W: \$15 — full APRS iGate
- Add RTL-SDR for receive-only iGate
- APRS-IS reports from your home QTH 24/7

APRS Applications: Beyond Simple Tracking



Mobile Tracking

Vehicles, marathons, bike races, SOTA activations — see everyone on a shared map



Weather Stations

WX objects: temp, wind, barometric pressure, rain — feeds Weather Underground



EmComm / ARES

Shelter locations, resource tracking, ICS-214 position reporting during activations



Aircraft / Balloons

High-altitude balloons (HABS), drones, experimental aircraft use APRS for tracking



Messages & Bulletins

Two-way APRS messaging between stations, NWS bulletins, national alerts



Satellite APRS

ISS on 145.825 MHz — digipeats your packet from orbit! PCSAT, RS-44 satellites



Events & Races

Event tracking: Tour de Cure, ARRL Field Day, SAR operations, marathons



Telemetry

Remote sensor data: battery voltage, solar input, temperature — structured format

APRS in Emergency Communications

APRS + EmComm = Situational Awareness

- Real-time tracking of mobile units (SAR teams, EOC vehicles)
- Shelter location broadcasting — OBJECT format
- Resource status via APRS messages and bulletins
- Works when internet is down — RF backbone
- Integrates with ICS-214 activity logs
- ARESMAT teams use APRS for cross-county coordination
- APRS frequency plan should be in every ARES go-kit
- El Paso County ARES: K6IG-10 iGate online 24/7
- PPRAA members encouraged to beacon during activations

APRS EmComm Quick Card

Freq	144.390 MHz
Mode	FM Simplex
Baud	1200 AFSK
Path	WIDE1-1,WIDE2-1
Rate	5-10 min fixed
Smart	Enabled if mobile
ISS	145.825 MHz
Symbol	-\$ (EOC) ▲ (SAR)

GPS Error Sources: Why Accuracy Varies

Ionospheric Delay	1-5 m	<i>Dual-frequency receivers (L1+L5)</i>
Tropospheric Delay	~0.5 m	<i>Model corrections applied by receiver</i>
Ephemeris Error	~1 m	<i>Regular upload from Control Segment</i>
Clock Error (Sat)	~1 m	<i>Atomic clocks + ground correction</i>
Multipath (Reflections)	1-10 m	<i>Choke ring antennas, open sky view</i>
Receiver Noise	~0.3 m	<i>Better ADC, more averaging time</i>
Geometric (PDOP)	Multiplier	<i>More satellites in view = better DOP</i>

Modern APRS Tools & Software Stack

aprs.fi

Web / Mobile

The de-facto APRS map. Global real-time tracking, history, weather, objects. Free.

aprs.fi

Direwolf

Software TNC

Open-source TNC for Linux/Windows. Digipeater + iGate. Best Pi option.

github.com/wb2osz/direwolf

APRSIS32

Windows Client

Full-featured Windows APRS client. Excellent mapping, filters, messaging.

aprsisce.com

Xastir

Linux Client

Classic Linux APRS client. Topo maps, WX alerts, SAR tools.

xastir.org

APRSdroid

Android App

APRS via phone audio, Bluetooth TNC, APRS-IS. Best mobile app.

aprsdroid.org

Ham Radio Sandwich

Pi Bundle

Raspberry Pi image with Direwolf, YAAC, GPS pre-configured.

n5dux.com/ham/hampi

Live Demo: aprs.fi — Colorado Springs



LIVE MAP DISPLAY

aprs.fi/k6ig

*[Navigate to site
during presentation]*

Demo Tips

- Search: K6IG
- Filter: Colorado Springs
- Click track history
- Show weather WX
- Click satellite view
- Show raw packets
- Check ARES objects
- [aprs.fi/k6ig-9](#)

Getting Started with APRS — Your First Steps

01

Listen First

Visit aprs.fi — search Colorado Springs. Watch the network for a week. You'll see what's active locally.

02

Set Up Receive-Only iGate

Raspberry Pi + RTL-SDR dongle (\$25 total) + Direwolf. Gate local packets to APRS-IS. No transmitting — no license needed for this part!

03

Get Your GPS Position on aprs.fi

APRSdroid on Android + APRS-IS login. Your phone GPS → internet → map. Instant gratification, no radio yet.

04

First RF Transmission

Baofeng UV-5R + \$10 cable + APRSdroid Bluetooth TNC mode. Set path WIDE1-1, beacon rate 2 min. You're on the air!

05

Mobile APRS

Add GPS tracker (BYonics or Mobilinkd TNC3) to your VHF radio. Smart-beacon for efficient road tracking.

06

ARES Integration

Register your station with El Paso County ARES. Add to APRS EmComm plan. Participate in exercises.

APRS in the Pikes Peak Region

Local APRS Infrastructure

- K6IG-10: iGate at 6,200 ft, east Colorado Springs
- Multiple digipeaters covering Pikes Peak region
- WOTLM — PPRAA club station APRS-capable
- ARES El Paso County maintains APRS coverage map
- WIDEn-N coverage: I-25 corridor well-served
- High sites: Pikes Peak (14,115 ft!) — occasional propagation
- APRS often linked to EmComm net activations
- Megafest 2026 — live APRS tracking for vendors & events



Pikes Peak
14,115 ft MSL

Colorado Springs
APRS Coverage

- 144.390 MHz primary
- iGates: multiple active
- 24/7 APRS-IS feed
- EmComm ready

The Future of GPS & APRS

GPS Modernization

- GPS Block III: new L1C signal (interoperable with Galileo)
- L5 signal now on all new Block III satellites
- M-code military signal — improved anti-jam
- Dual-frequency now standard in phones (iPhone 14+)
- RTK-over-cellular: centimeter accuracy, consumer price
- LEO augmentation (Starlink?) — seconds to first fix
- GPS anti-spoofing becoming critical infrastructure issue
- Quantum navigation: GPS backup without satellites

APRS Evolution

- APRS 2.0 discussion ongoing in TAPR community
- LoRa APRS (433/915 MHz) — longer range, lower power
- Improved symbol set and message compression
- Integration with D-RATS and Winlink for hybrid data
- APRS over D-STAR and System Fusion (digital modes)
- Mesh networking (AREDN) + APRS hybrid systems
- Better EmComm integration with EOC software (WebEOC)
- APRS remains the gold standard for portable tracking

Key Takeaways



GPS grew from Cold War necessity — two physicists tracking Sputnik with Doppler shift sparked it all



The U.S. Navy's Transit system proved the satellite navigation concept through the 1960s–90s



NAVSTAR GPS took a single visionary weekend in 1973 to design — then 22 years to build



Turning off Selective Availability in 2000 unleashed GPS for the entire world — freely, forever



APRS bridges GPS position data with amateur radio VHF — creating a live mesh awareness network



In emergencies, APRS works when phones don't — it's a resilient, infrastructure-independent system

Resources & Further Reading

GPS History

- "The GPS Story" — Bradford Parkinson, IEEE Spectrum
- "GPS and the Search for Precise Time" — Dana Peters
- GPS.gov — official government history site

APRS Learning

- WB4APR.com — Bob Bruninga's original APRS pages
- "APRS — Moving Hams on Radio and the Internet" — Bob Bruninga
- aprs.fi — start here, look at your area live

Software & Tools

- Direwolf manual: WB2OSZ GitHub
- APRSIS32 wiki: aprsisce.com/wiki
- APRSdroid: aprsdroid.org

Local / EmComm

- PPRAA: ppraa.org — club website
- El Paso County ARES: w0t1m.com
- K6IG iGate: aprs.fi/k6ig-10

Acronym & Abbreviation Reference

Navigation Systems & Programs

GPS	Global Positioning System
GNSS	Global Navigation Satellite System
NAVSTAR	Navigation System with Timing and Ranging
GLONASS	Russian GNSS — Globalnaya Nav. Sputnikovaya Sistema
TRANSIT	Navy satellite nav predecessor to GPS (1960–1996)
TIMATION	Time Navigation — NRL orbital clock program (NRL)
LORAN-C	Long Range Navigation – Chain, 100 kHz hyperbolic

Agencies & Laboratories

NRL	Naval Research Laboratory, Washington D.C.
NBS	National Bureau of Standards (now NIST)
NIST	National Institute of Standards & Technology
APL	Applied Physics Lab, Johns Hopkins University
FAA	Federal Aviation Administration
USCG	United States Coast Guard
DoD	Department of Defense
DHS	Department of Homeland Security

GPS Technical Terms

SA	Selective Availability — intentional accuracy degradation
PRN	Pseudo-Random Noise code — satellite identifier
MEO	Medium Earth Orbit (~20,200 km altitude)
GEO	Geostationary Earth Orbit (~35,786 km)
PDOP	Position Dilution of Precision
HDOP	Horizontal Dilution of Precision
SV / SVs	Space Vehicle(s) — GPS satellite(s)
FOC	Full Operational Capability
IOC	Initial Operational Capability

Augmentation Systems

WAAS	Wide Area Augmentation System (FAA)
DGPS	Differential GPS
NDGPS	Nationwide Differential GPS (USCG → FAA)
LAAS/GLS	Local Area Aug. System / GPS Landing System
LPV	Localizer Performance w/ Vertical guidance
ILS	Instrument Landing System (legacy approach)
RTK	Real-Time Kinematic — centimeter-level GPS

Military GPS

PLGR	Precision Lightweight GPS Receiver ("Pluggger")
BFT	Blue Force Tracker — GPS + satellite data link
FBCB2	Force XXI Battle Command, Brigade & Below
MUOS	Mobile User Objective System (military sat.)
INMARSAT	International Maritime Satellite (BFT-1 link)

APRS & Ham Radio

APRS	Automatic Packet Reporting System
TNC	Terminal Node Controller
AFSK	Audio Frequency Shift Keying (1200 baud)
NMEA	Natl. Marine Electronics Assoc. — GPS serial format
IGate	Internet Gateway — bridges RF APRS to APRS-IS
APRS-IS	APRS Internet Service — global TCP/IP backbone
SSID	Secondary Station Identifier (e.g., K6IG-9)
ARES	Amateur Radio Emergency Service
RACES	Radio Amateur Civil Emergency Service
EmComm	Emergency Communications
QTH	Ham shorthand for station location

Questions & Discussion

*From Sputnik's beep to your APRS tracker
the same physics connect them all.*

73 de K6IG

144.390 MHz · aprs.fi/k6ig · ppraa.org

