# ERTH 491-01 / GEOP 572-02
# Geodetic Methods

## – Lecture 03: GPS Overview–

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# GPS Overview

- 1973: Architecture approved
- 1978: First Block-I satellite launched
- 1983: Korean Air 007 shot down after straying into USSR air space
- 1983: Pres. Reagan mandated civilian use of GPS
- 1985: 10 Block-I satellites in orbit for concept test
- 1995: Full Operational Capability (FOC)
- 2000: Selective availability turned off

GPS Block-I, *NASA*

# GPS Overview

- 2005: Begin modernization, First Block IIR-M broadcasts L2C signal
- 2010-2015: 10/12 Block IIF satellites launched, broadcast L5 signal
- 2017 (?) Block III launches: new signals – Military (M-code), L1C, increased signal power, laser retro-reflectors for orbit tracking,
- total satellite launches: 66, only 2 failures!

GPS Block-IIIA, *NASA*

# GPS Primary Uses

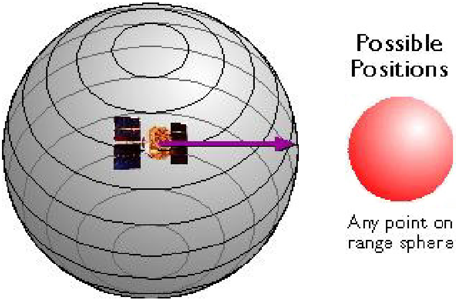
### Navigation

real-time, meter accuracy (sub-meter in differential mode)

### Surveying

post-processing, multi-receiver, millimeter accuracy

# GPS Positioning (in a Nutshell) – Ranging




*https://www.e-education.psu.edu/geog482spring2/c5_p18.html*

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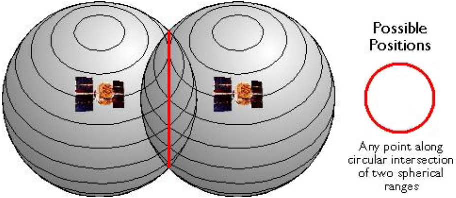


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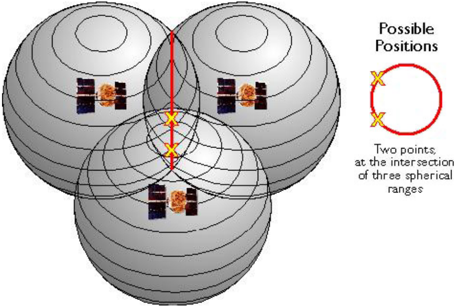


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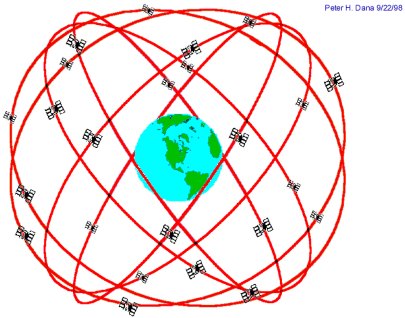
# System Architecture

- Space Segment – satellites
- Control Segment – management of satellites
- User Segment – Civil and military receiver development

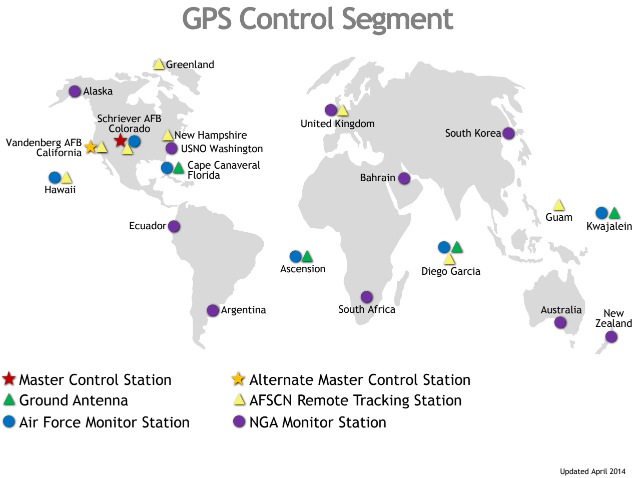
# System Architecture: Space Segment

- Baseline constellation 24 satellites, 6 orbital planes, 55° inclined
- Period $\approx$ 12 hours, stationary ground tracks
- Currently 32 satellites operational
- Constellation Status / Outages: `http://www.navcen.uscg.gov/`
- E.g. `http://navcen.uscg.gov/?Do=constellationStatus`




**GPS Nominal Constellation**
**24 Satellites in 6 Orbital Planes**
**4 Satellites in each Plane**
**20,200 km Altitudes, 55 Degree Inclination**

# System Architecture: Control Segment




*gps.gov*

Master control station (Colorado) operates system, sends commands

# System Architecture: Control Segment

- monitor orbits, satellite health
- maintain GPS time (currently 17 s ahead of UTC)
- predict ephemerides, clock parameters
- update satellite navigation messages
- maneuver satellite: maintain orbit

| | | | | |
|---|---|---|---|---|
| **local** | 2015-08-23 21:06:20 | Sunday | day 235 | timezone UTC-6 |
| **UTC** | 2015-08-24 03:06:20 | Monday | day 236 | MJD 57258.12939 |
| **GPS** | 2015-08-24 03:06:37 | week 1859 | 97597 s | cycle 1 week 0835 day 1 |
| **Loran** | 2015-08-24 03:06:46 | GRI 9940 | 349 s until | next TOC 03:12:09 UTC |
| **TAI** | 2015-08-24 03:06:56 | Monday | day 236 | 36 leap seconds |

*http://www.leapsecond.com/java/gpsclock.htm*

# System Architecture: Control Segment

- each satellite visible at min 2 monitor stations
- monitor stations operated remotely from MCS
- equipment: GPS receivers w/ cesium clocks, met instruments, comms to satellites
- GPS time based on atomic clocks on satellites and monitor stations
- satellite clock time offset, drift, drift rate part of navigation message, allows clock sync

# System Architecture: User Segment



# Signals

- continuous transmission on 2 L-band radio frequencies: Link 1 (L1), Link 2 (L2) (for legacy GPS)
- L1 ($f_{L1}$ = 1575.42 MHz): 1 signal for civil users, 1 for military
- L2 ($f_{L2}$ =1227.60 MHz): 1 signal military
- L3 (1381.05 MHz): classified – associated w/ Nuclear Detonation Detection System
- L4 (1379.913 MHz): classified – no transmission, maybe additional ionosphere correction in future
- L5 (1176.45 MHz): (future) Safety of Life; civilian use

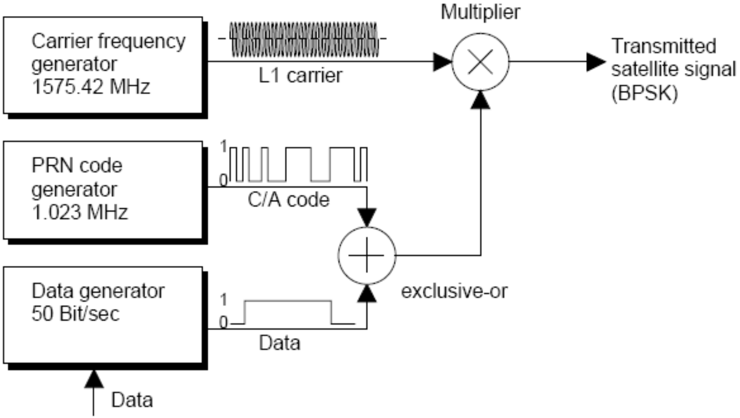
# Signals: Structure

Detailed in Interface Specification (IS-GPS-200D):

`http://www.navcen.uscg.gov/pdf/IS-GPS-200D.pdf`

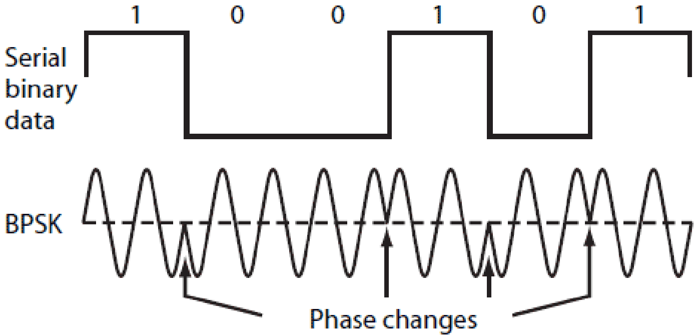
- *Carrier:* sinusoidal signal with $f_{L1,2}$, derives from 10.23 MHz atomic clock
- *Ranging Code:* pseudo-random noise (PRN) sequences unique to satellite
  - orthogonal to each other: no interference on same frequency
  - uncorrelated with itself, autocorrelation is zero unless perfect overlap
  - civilian: “Coarse/aquisition codes” (C/A codes) on L1
  - **C/A:** 1023 bits (chips), repeated each millisecond
  - each C/A chip $\approx 1\mu$s, chip width $\approx$300 m
  - military use, hence “Precision codes” (P(Y) is encrypted P-code) on L1,L2
  - **P-codes** extremely long PRN, part of master code
  - repeats after 1 week: C/A code for easier locking
- *Navigation Data:* satellite health, position, velocity, clock bias parameters, almanac (information/status on several/all satellites)

# Signals: Structure




from: *http://www.ni.com/tutorial/7139/en/*

# Signals: Modulation




2. In binary phase shift keying, note how a binary 0 is 0° while a binary 1 is 180°. The phase changes when the binary state switches so the signal is coherent.

from: `http://www.electronicdesign.com`