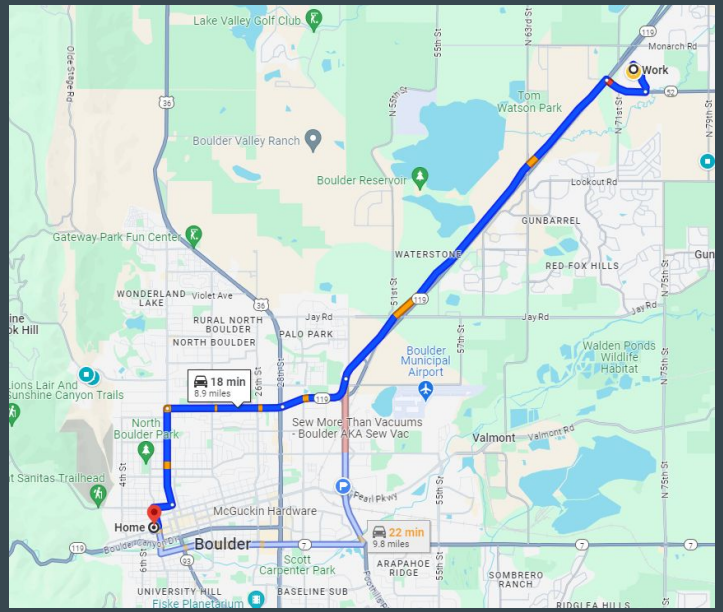
Einstein Made Google Maps Work

Nathan Seidle - SparkFun Electronics


sparkfun
OPEN
DENVER
3


Work
Home
Boulder
18 min
8.9 miles
22 min
9.8 miles
Lake Valley Golf Club
Boulder Valley Ranch
Boulder Reservoir
Tom Watson Park
Gateway Park Fun Center
WATERSTONE
GUNBARREL
RED FOX HILLS
WONDERLAND LAKE
RURAL NORTH BOULDER
NORTH BOULDER
PALO PARK
Boulder Municipal Airport
Walden Ponds Wildlife Habitat
North Boulder Park
Sew More Than Vacuums - Boulder AKA Sew Vac
Valmont
McGuckin Hardware
Scott Carpenter Park
ARAPAHOE RIDGE
SOMBRERO RANCH
UNIVERSITY HILL
Fiske Planetarium
BASELINE SUB
RIDGLEA HILLS

Basics

- Sputnik (1957) was tracked via Doppler shift
- First gen GPS sat launched in 1978
- Full GPS constellation in 1994
- 77 GPS satellites launched over 44 years
- 12 hour path = Not Geosynchronous, Medium Earth Orbit
  - ~12,000 miles (19,000 km) away
  - ~8,000 mph (14,000 km/hr)
- <50W !


WC
5

GNSS = GPS + Everyone

- GPS (30) - USA’s global navigation system.
- GLONASS (24) - Russia's global navigation system.
- Galileo (24) - European Union’s global navigation system.
- BeiDou (28) - People's Republic of China's global navigation system.
- IRNSS (8) - India's regional navigation system, covering India and Northern Indian Ocean.
- QZSS (4) - Japanese regional system covering Asia and Oceania.

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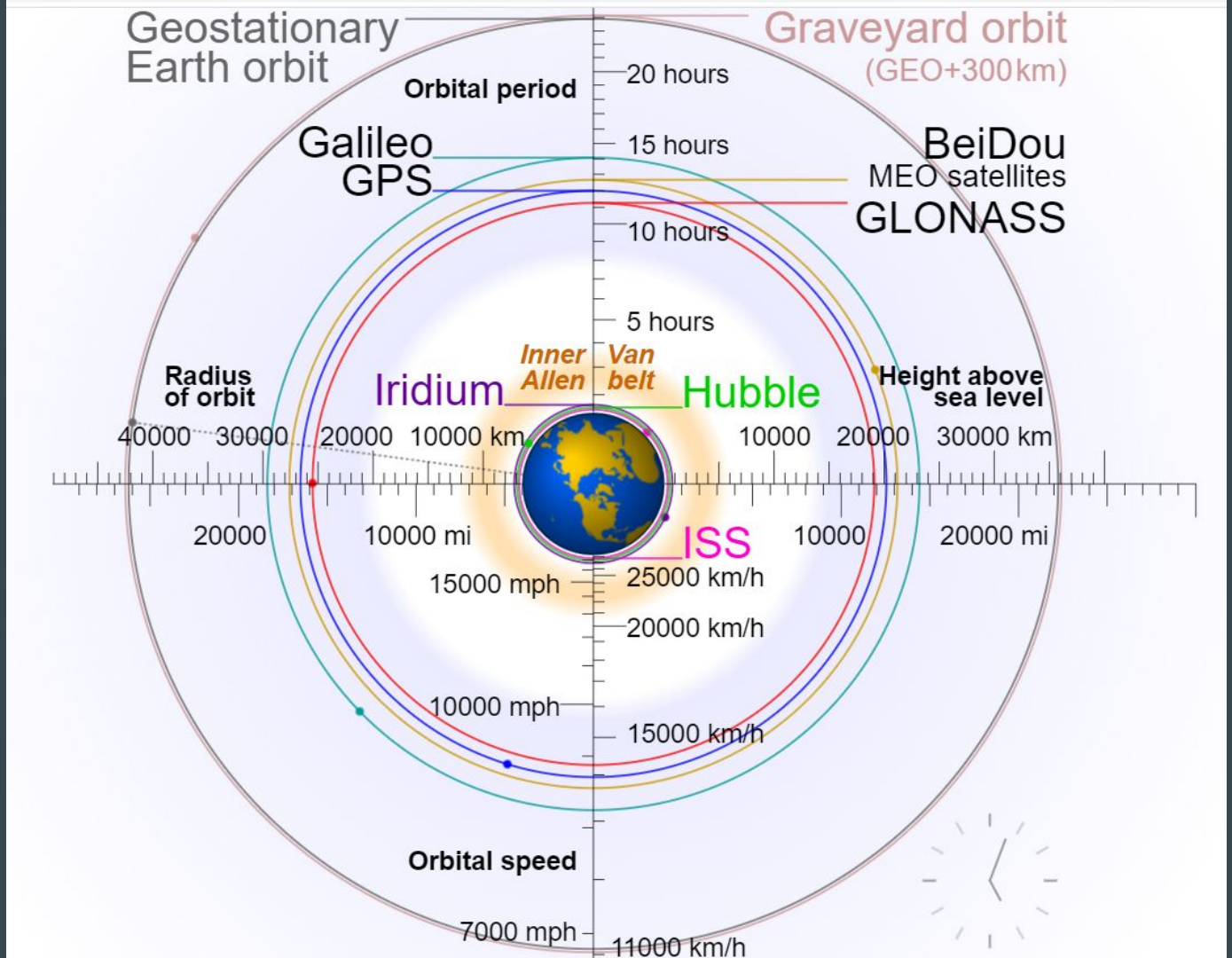
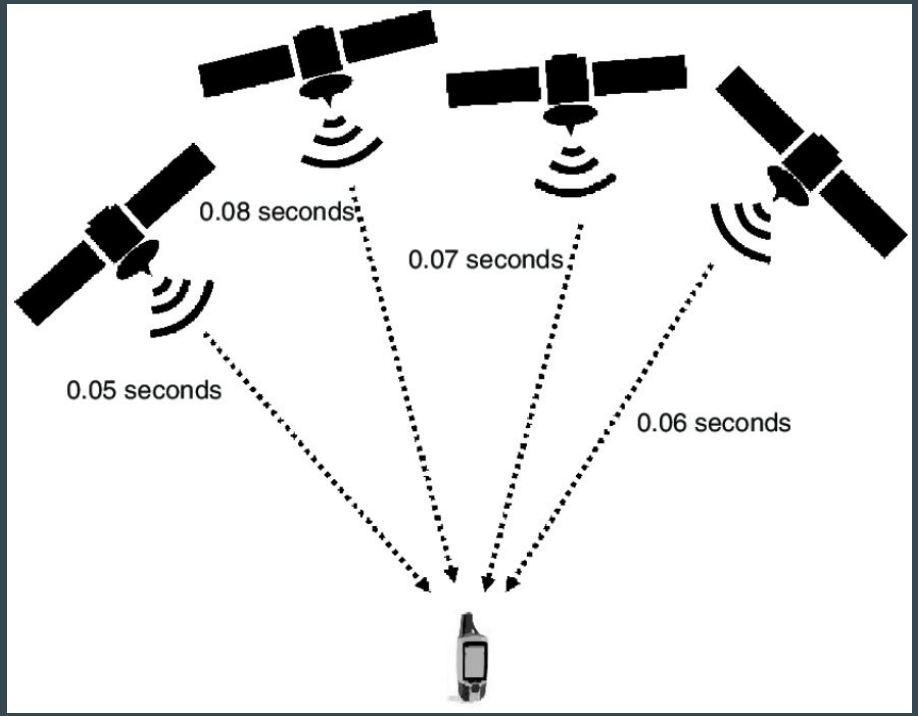
Ask yourself - Where do I plan to deploy troops someday?


Geostationary
Earth orbit
Graveyard orbit
(GEO+300 km)
Orbital period
20 hours
15 hours
10 hours
5 hours
Galileo
GPS
BeiDou
MEO satellites
GLONASS
Inner
Allen
Van
belt
Radius
of orbit
Iridium
Hubble
Height above
sea level
40000
30000
20000
10000 km
10000
20000
30000 km
20000
10000 mi
10000
20000 mi
ISS
15000 mph
25000 km/h
20000 km/h
10000 mph
15000 km/h
Orbital speed
7000 mph
11000 km/h

Trilateration

- Satellites transmit: “Hi, I’m #5. It’s 2:15PM. I am feeling ok. ”
- A receiver crunches the numbers between 10+ satellites.
- Output is a +/- 2m location (and time)



Cesium Clocks, LASERs, and Relativity

- “...one microsecond creates an error of 300 meters.” - HMC Geophysics
- “...the predicted orbits are often off by one meter or more. Ground stations bounce lasers off the individual satellites as they pass overhead...” - Gary Miller
- “Relativistic principles and effects which must be considered include the constancy of the speed of light, the equivalence principle, the Sagnac effect, time dilation, gravitational frequency shifts, and relativity of synchronization.”- Neil Ashby

Relativity... Fight!

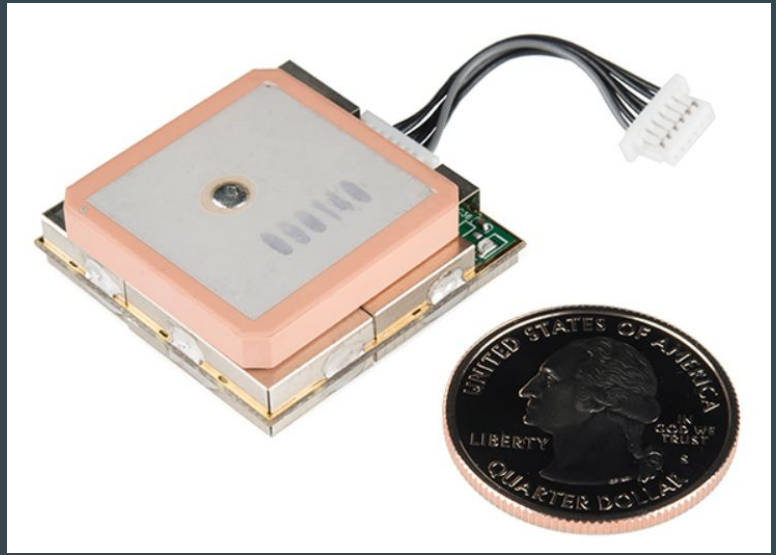
- Special: “**A moving clock ticks more slowly when compared with one that’s stationary at sea level.** A clock aboard a GPS satellite will lose about 7 microseconds per day. “
- General: “A clock in a weaker gravitational field will tick faster than one that’s stationary at sea level... . A clock aboard a GPS satellite in a medium Earth orbit will gain about 45 microseconds per day over a clock that’s at sea level on the earth. - GPS World

45µs - 7µs = **38µs a day**

(That’s 616ms in the future since 1980...)

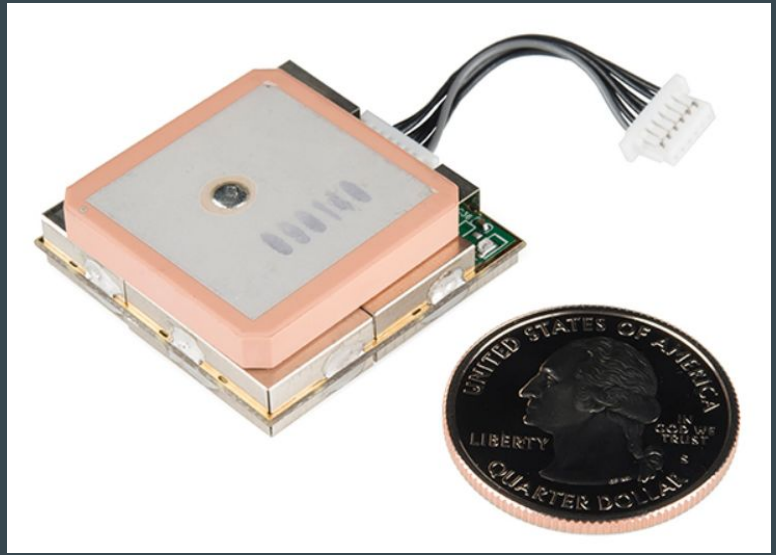
How To GPS

- Turn it on. Wait ~30s. Know where you are.
- ~2m / 6.5ft ‘off the shelf’
- Free!
- No, you cannot put it in your child*



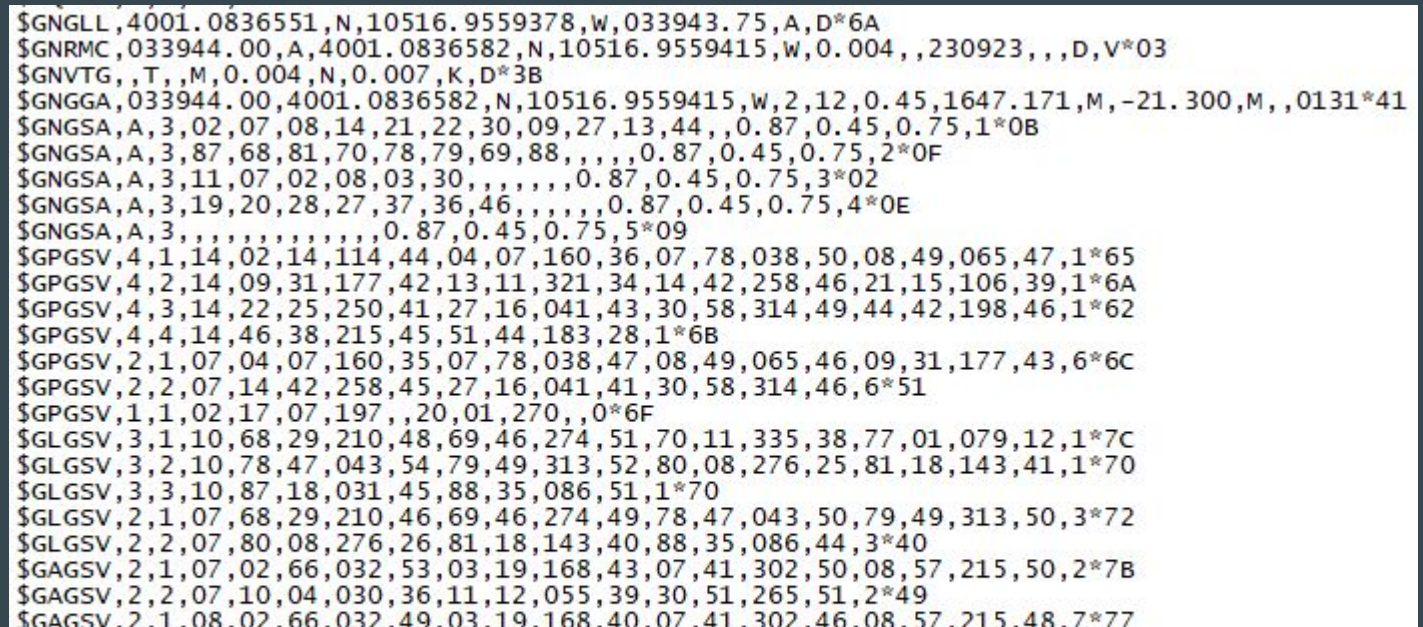
*Limitations

- Children are made of water
- 35mA = ~1 day on a AA
  (kids don't like having their batteries changed)
- Make sure they never do cart wheels
- No, you cannot put it in your child.



NMEA What?

- National Marine Electronics Association
- *Every* GNSS receiver in the world outputs NMEA



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$GNVTG,,T,,M,0.004,N,0.007,K,D*3B
$GNGGA,033944.00,4001.0836582,N,10516.9559415,W,2,12,0.45,1647.171,M,-21.300,M,,0131*41
$GNGSA,A,3,02,07,08,14,21,22,30,09,27,13,44,,0.87,0.45,0.75,1*0B
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$GPGSV,4,4,14,46,38,215,45,51,44,183,28,1*6B
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$GLGSV,3,3,10,87,18,031,45,88,35,086,51,1*70
$GLGSV,2,1,07,68,29,210,46,69,46,274,49,78,47,043,50,79,49,313,50,3*72
$GLGSV,2,2,07,80,08,276,26,81,18,143,40,88,35,086,44,3*40
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$GAGSV,2,2,07,10,04,030,36,11,12,055,39,30,51,265,51,2*49
$GAGSV,2,1,08,02,66,032,49,03,19,168,40,07,41,302,46,08,57,215,48,7*77
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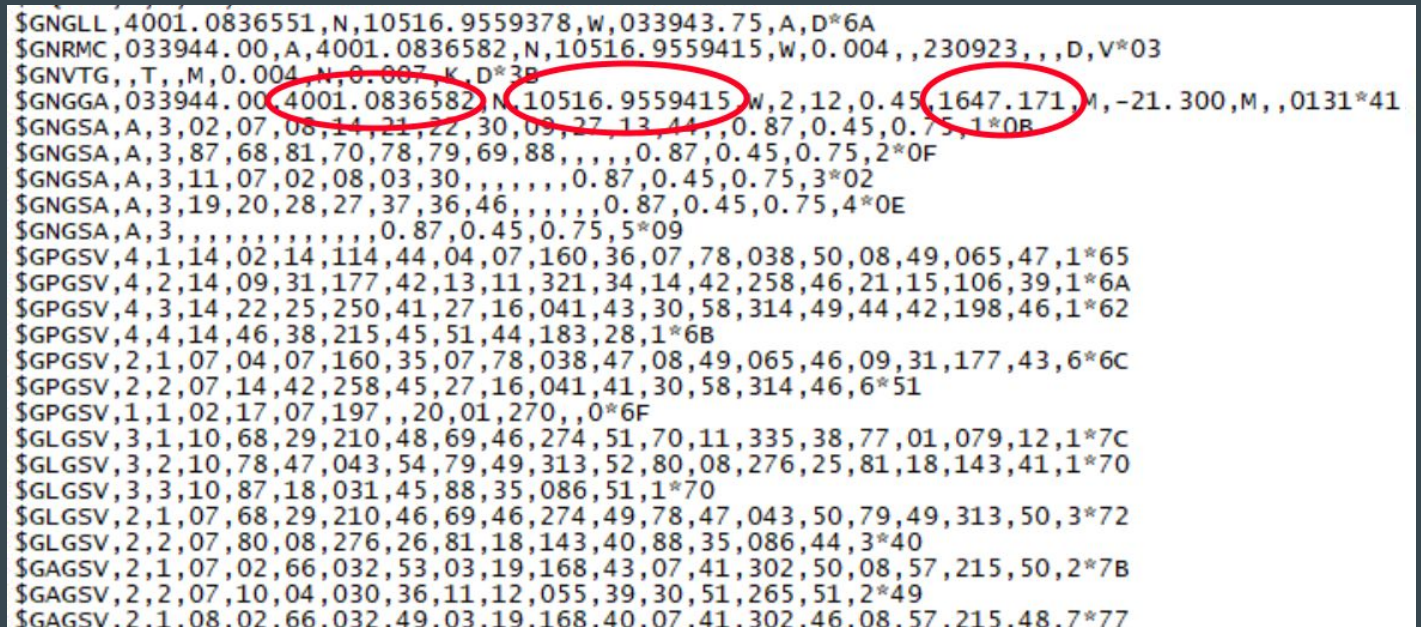

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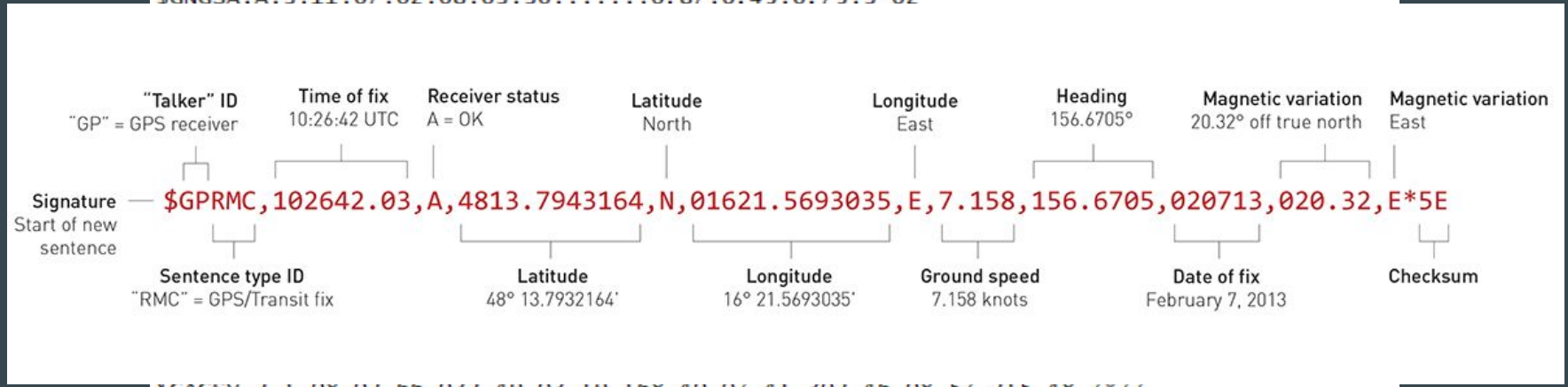
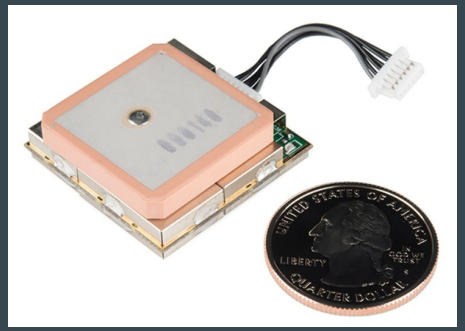
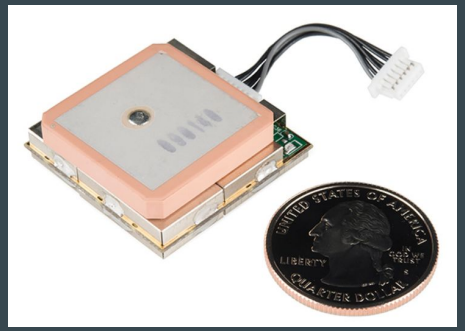


GPS L1
1994



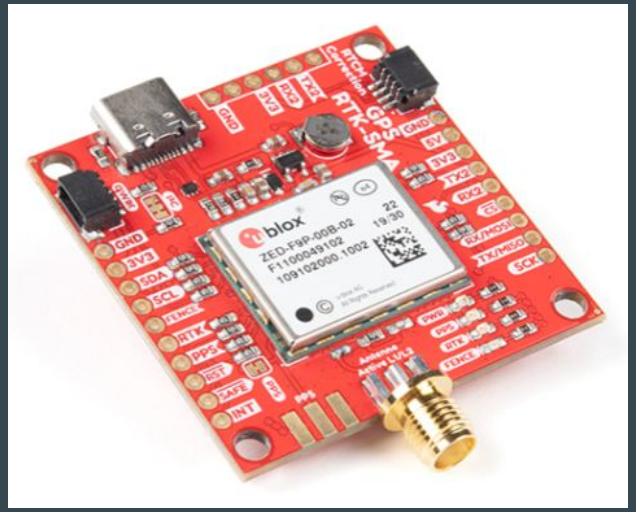
1.575 GHz

GPS L1
1994



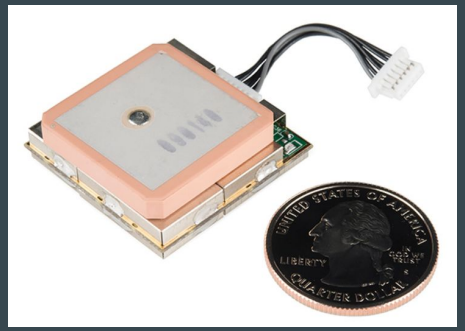
1.575 GHz

GPS L2
2005



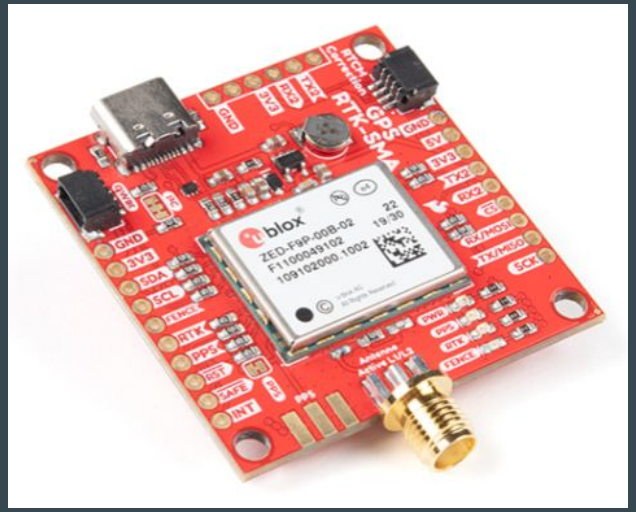
1.227 GHz

GPS L1
1994



1.575 GHz

GPS L2
2005

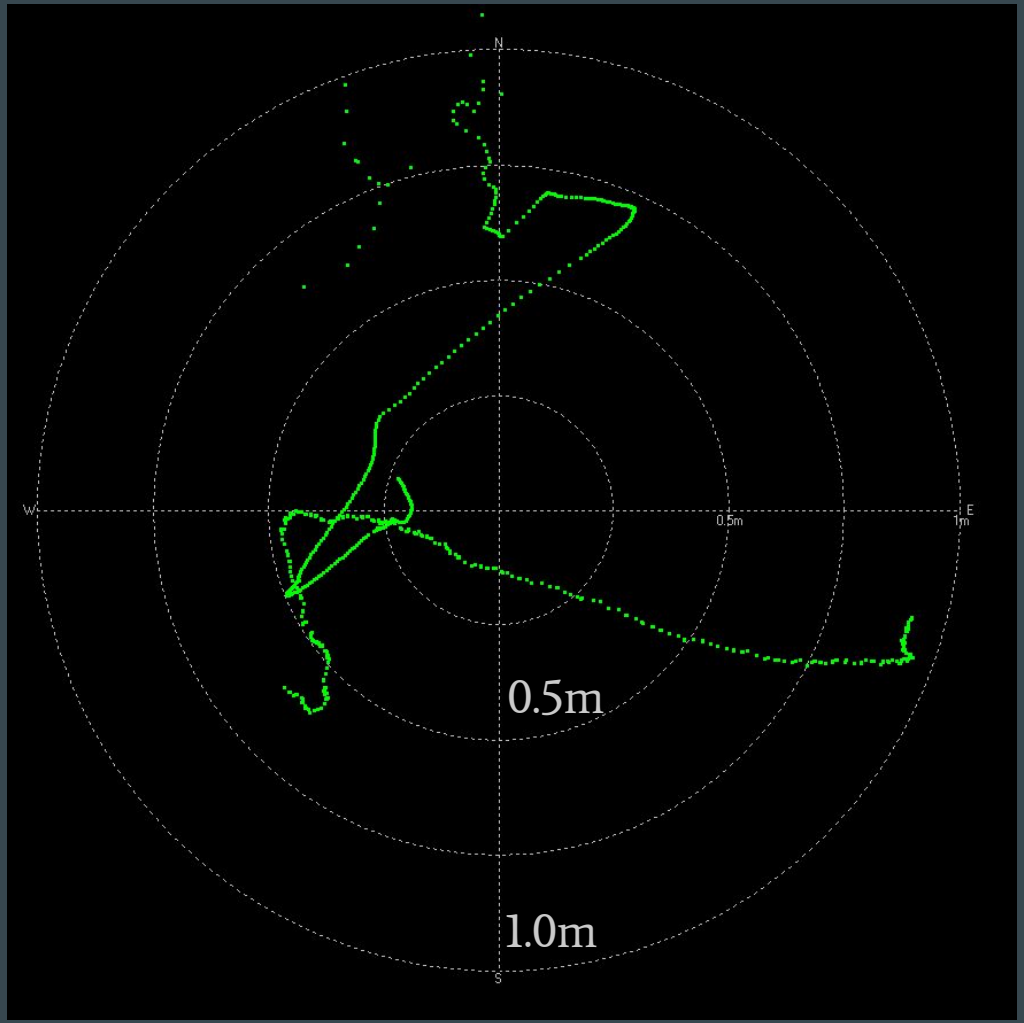


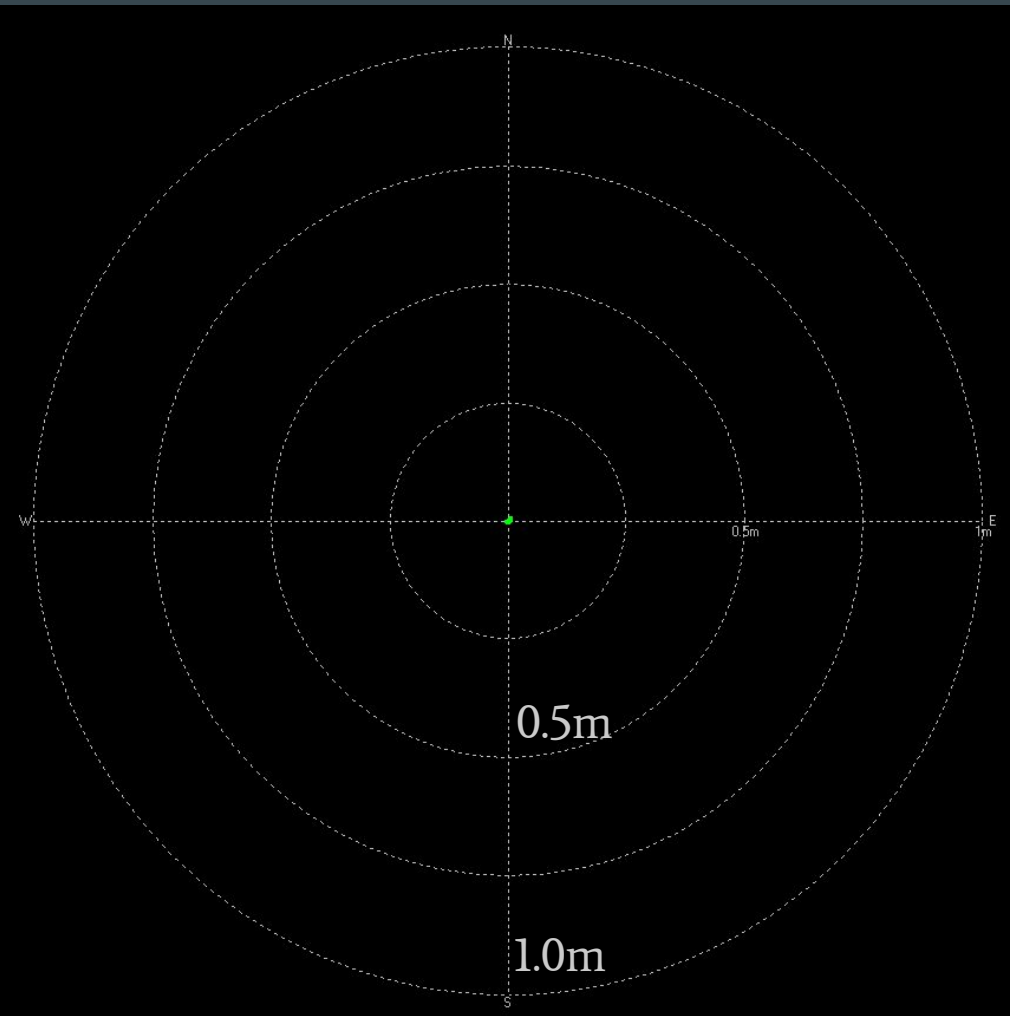
1.227 GHz

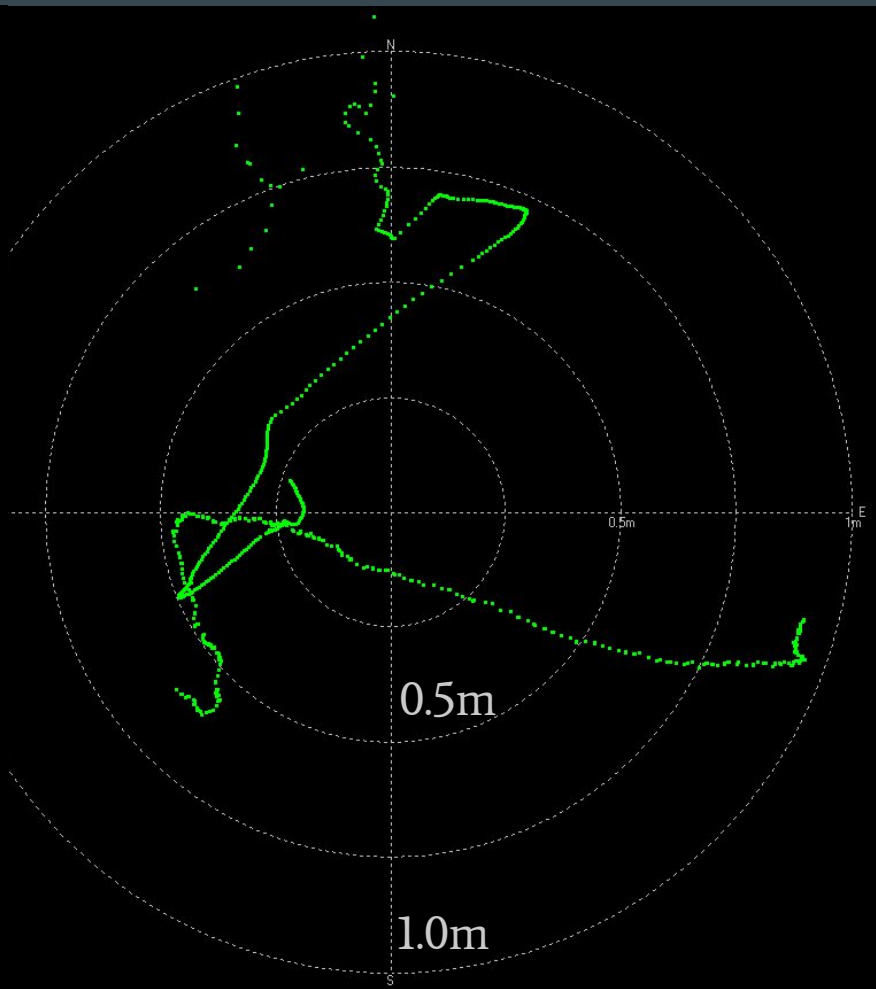
GPS L5
Pre-operational

1.176 GHz

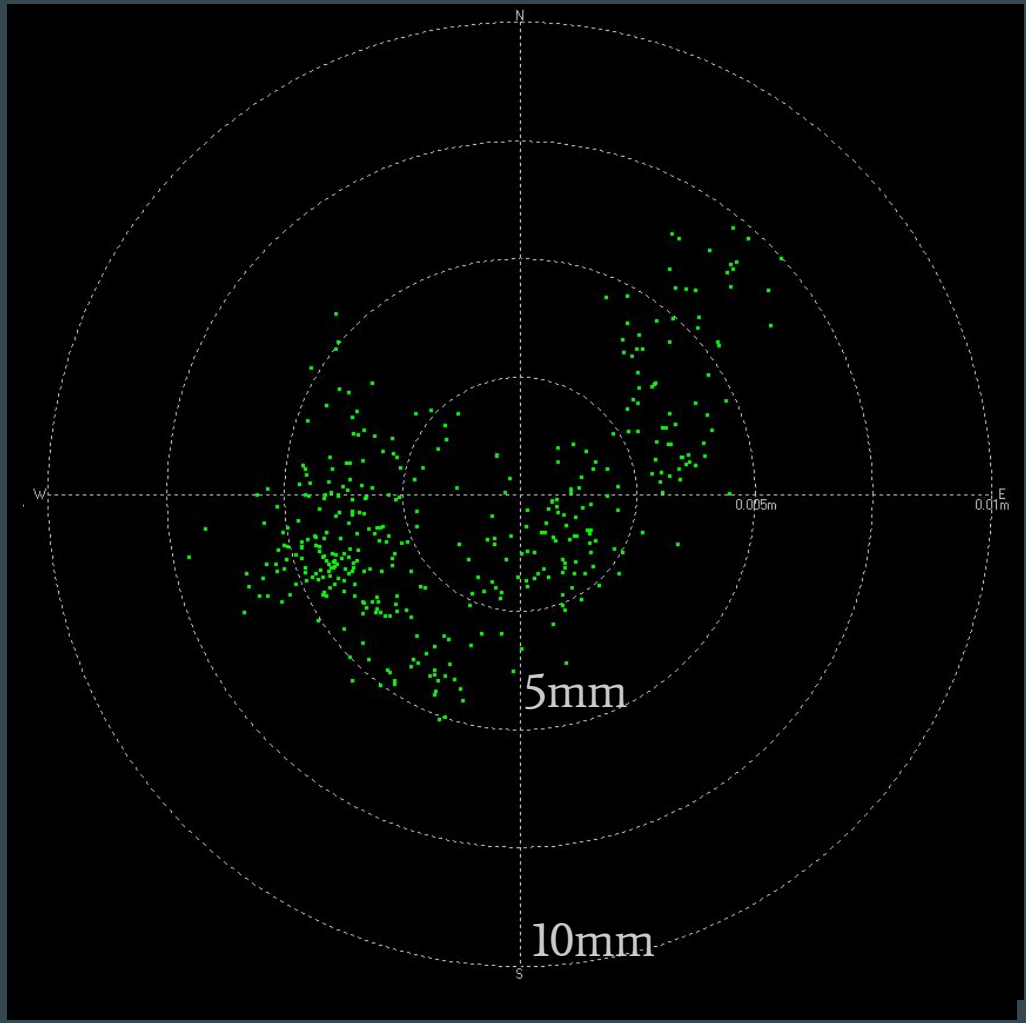
1m Accuracy




N
W
E
S
0.5m
1m
0.5m
1.0m

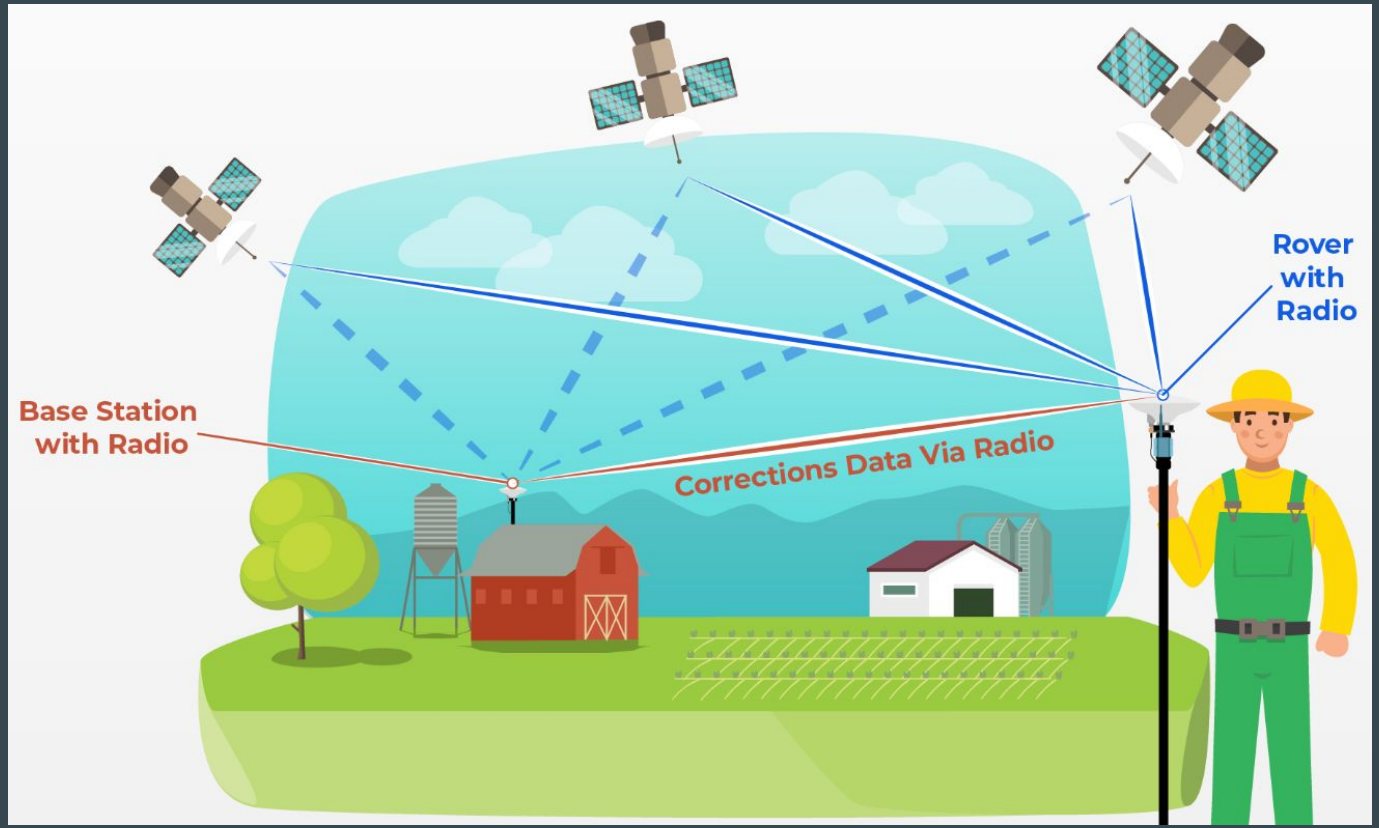

N
E
S
0.5m
1m
0.5m
1.0m

RTK = 10mm precision



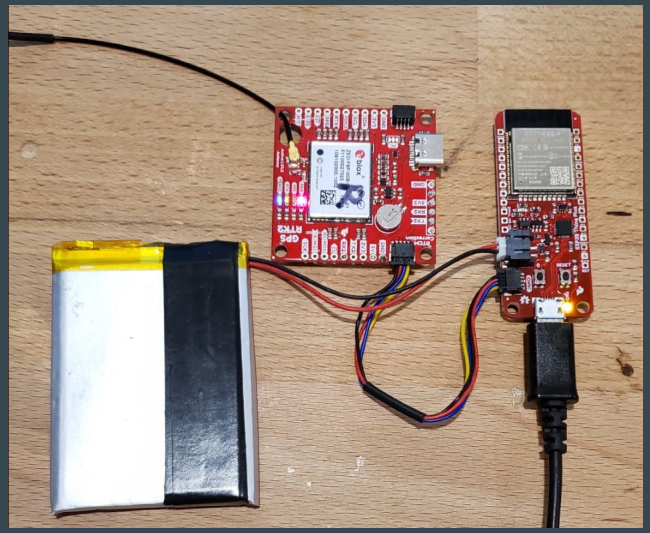
RTK = 10mm precision

RTK = Real Time Kinematics



State-wide Corrections

DIY Base Station



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STR;BIDEFORD;BIDEFORD;RTCM 3.3;1004(1),10
STR;bie001;Biervliet;RTCM 3.3;1004(1),100
STR;BlankFarm;Eimsiedlin;RTCM 3.3;1004(1)
STR;bldr_SparkFun1;Boulder, CO;RTCM 3.2;1
STR;Blue_Base;Avoca MN;CMR+;CMR+(1);0;;SN
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STR;BOBASL;Slepcevic;RTCM 3.2;1005(30),10
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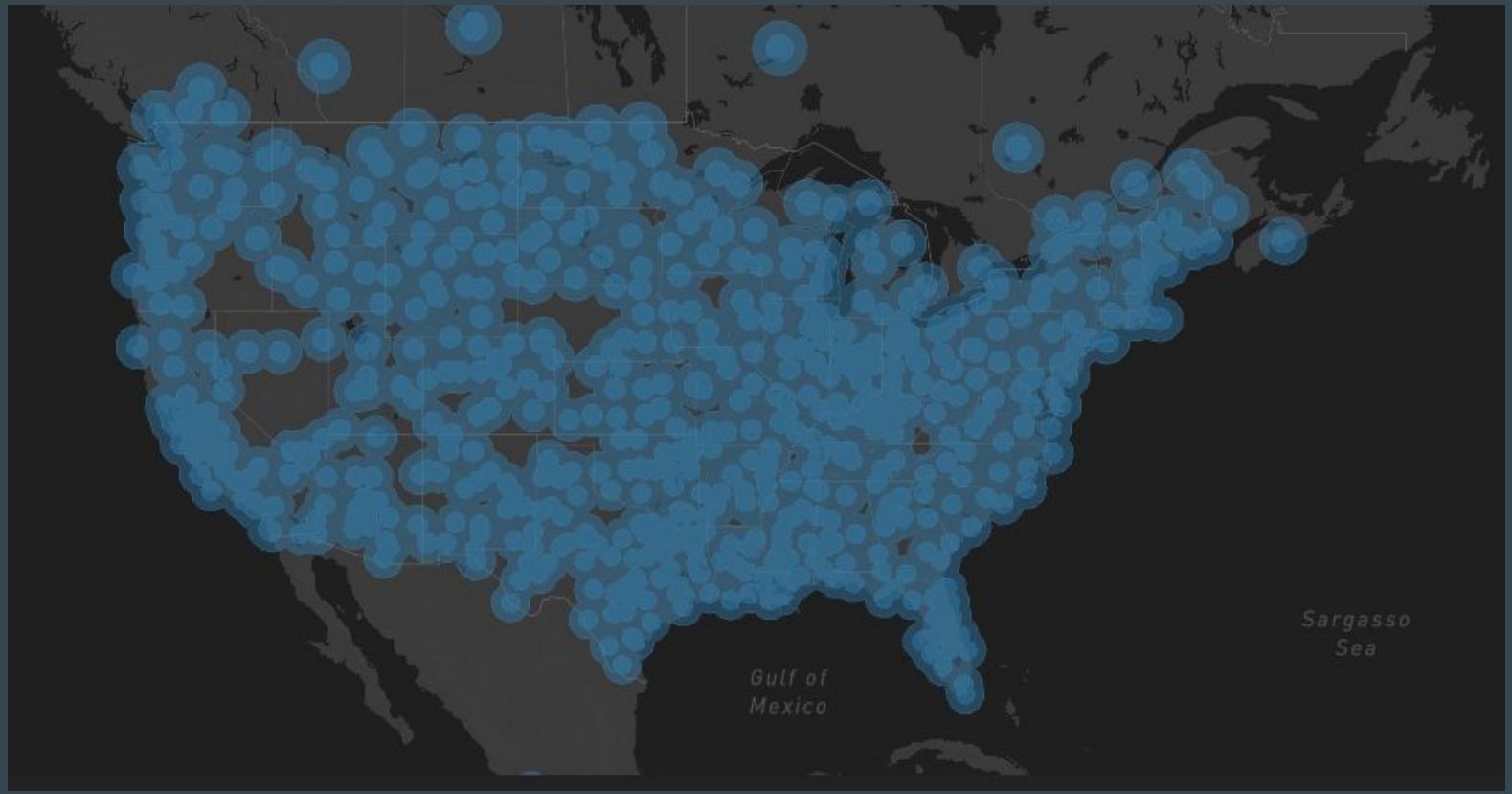
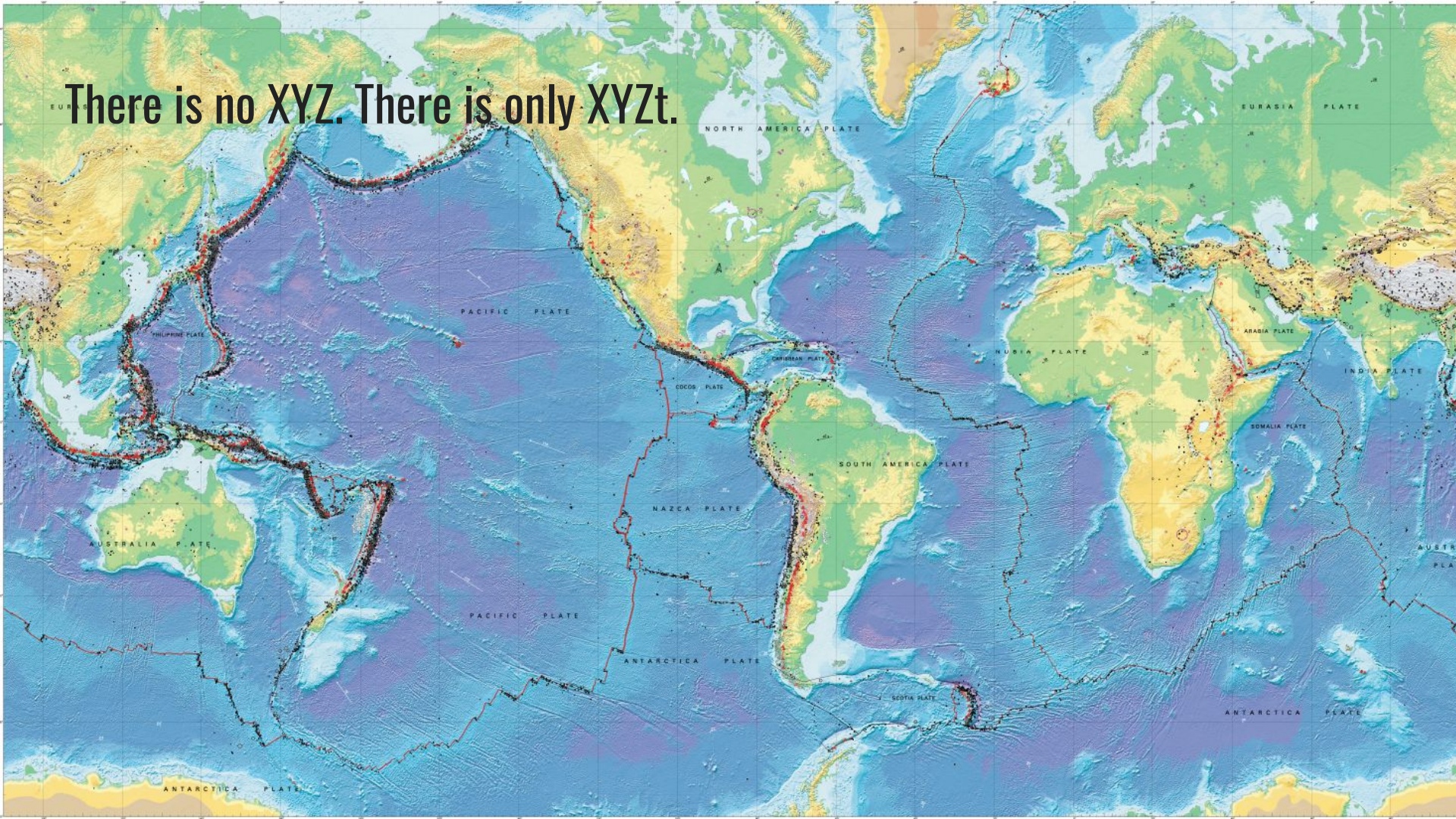
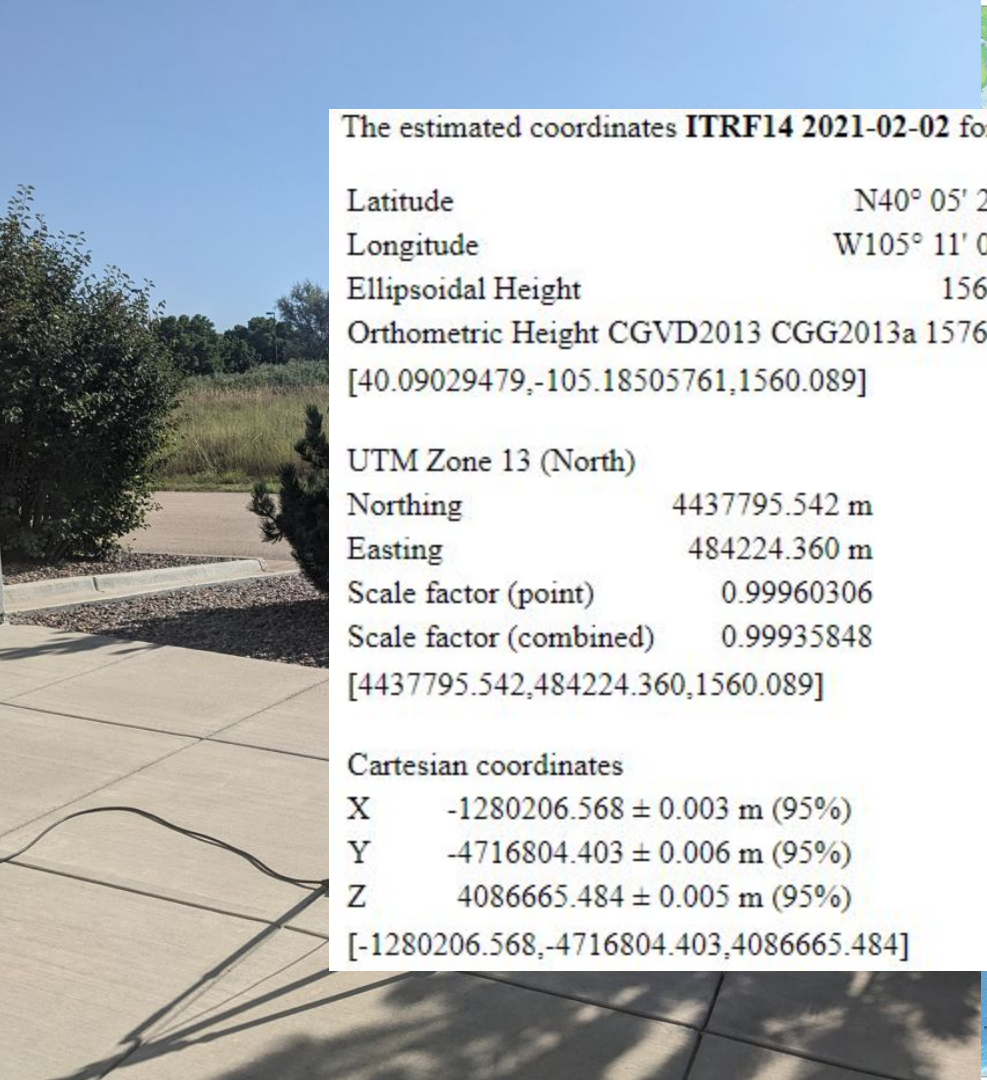
‘Pay For’ Corrections Networks




There is no XYZ. There is only XYZt.
NORTH AMERICA PLATE
EURASIA PLATE
PACIFIC PLATE
PHILIPPINE PLATE
CARIBBEAN PLATE
COCOS PLATE
NUBIA PLATE
ARABIA PLATE
INDIA PLATE
SOMALIA PLATE
SOUTH AMERICA PLATE
NAZCA PLATE
AUSTRALIA PLATE
PACIFIC PLATE
ANTARCTICA PLATE
SCOTIA PLATE
ANTARCTICA PLATE
ANTARCTICA PLATE


EURASIA PLATE
AMERICA PLATE
ARABIA PLATE
NUBIA PLATE
INDIA PLATE
SOMALIA PLATE
SOUTH AMERICA PLATE
SCOTIA PLATE
ANTARCTICA PLATE



The estimated coordinates **ITRF14 2021-02-02** for the **SparkFun UFO PPP 24 Hours 1Hz.obs**

Latitude	N40° 05' 25.0612" ± 0.002 m (95%)
Longitude	W105° 11' 06.2074" ± 0.002 m (95%)
Ellipsoidal Height	1560.089 m ± 0.008 m (95%)

Orthometric Height CGVD2013 CGG2013a 1576.6944 m

[40.09029479,-105.18505761,1560.089]

UTM Zone 13 (North)

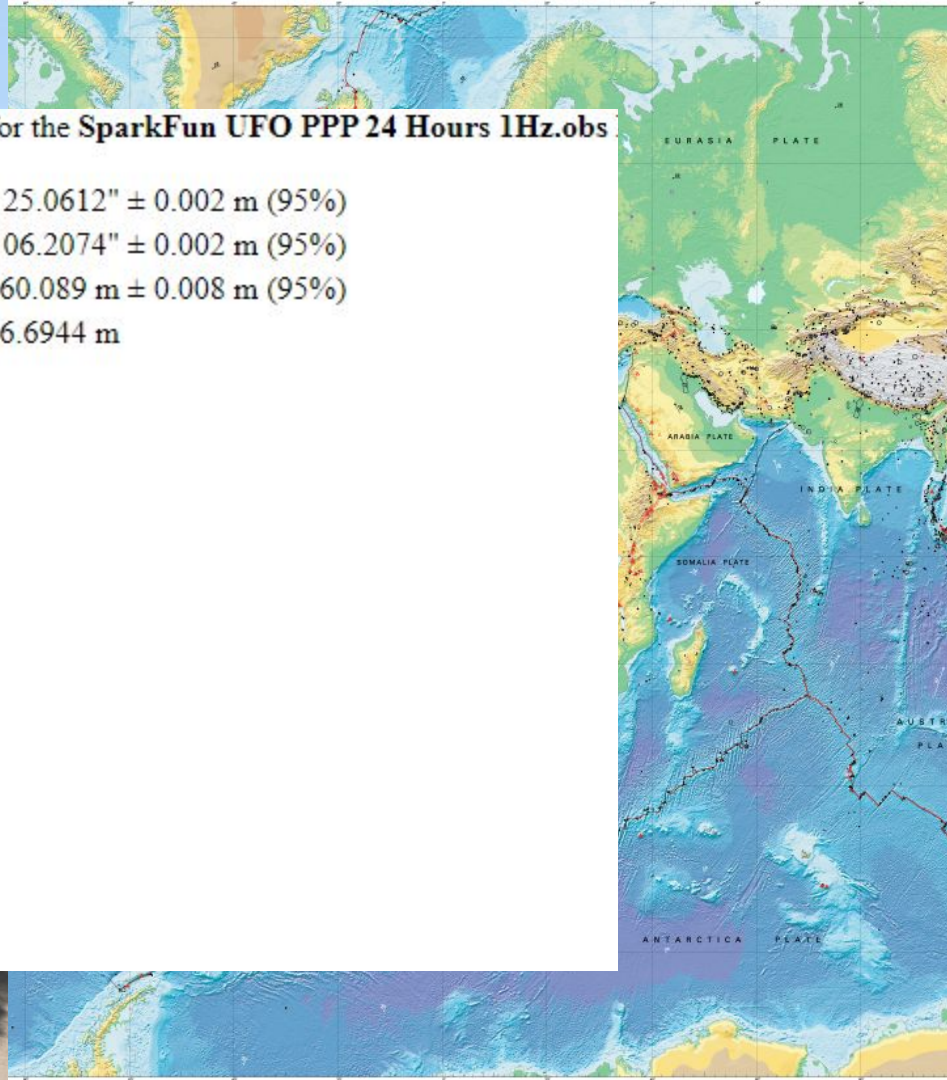
Northing	4437795.542 m
Easting	484224.360 m
Scale factor (point)	0.99960306
Scale factor (combined)	0.99935848

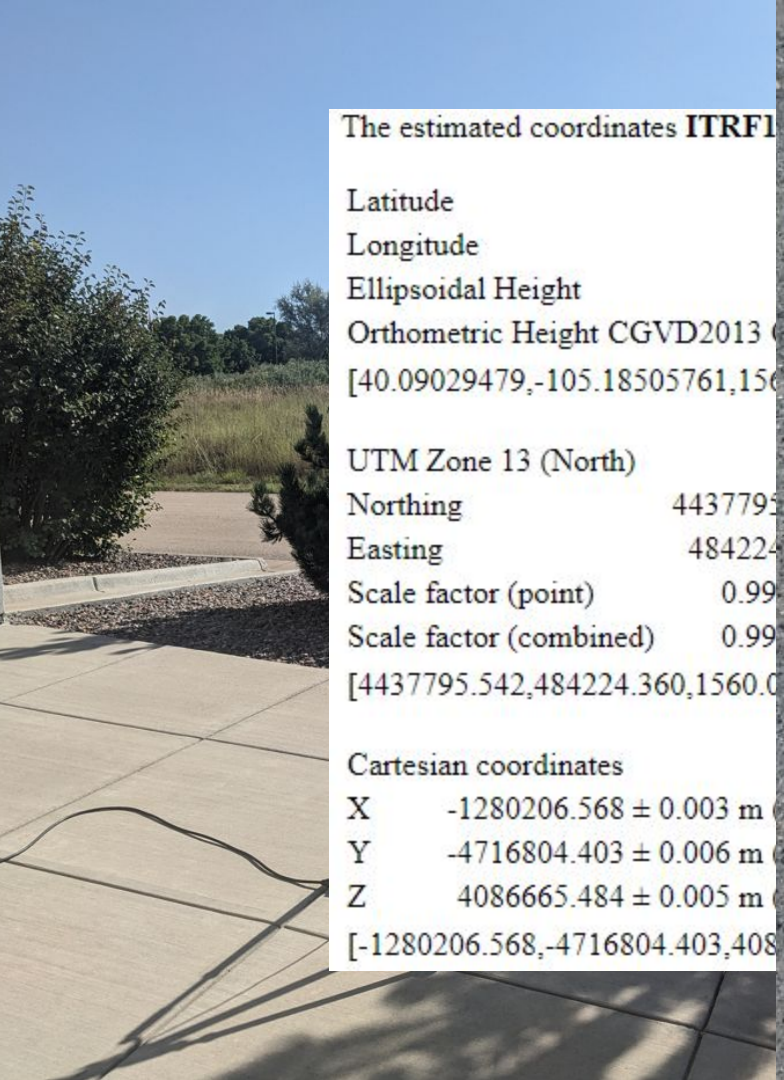
[4437795.542,484224.360,1560.089]

Cartesian coordinates

X	-1280206.568 ± 0.003 m (95%)
Y	-4716804.403 ± 0.006 m (95%)
Z	4086665.484 ± 0.005 m (95%)

[-1280206.568,-4716804.403,4086665.484]





The estimated coordinates **ITRF1**

Latitude	
Longitude	
Ellipsoidal Height	
Orthometric Height CGVD2013 (	
[40.09029479,-105.18505761,15(	

UTM Zone 13 (North)	
Northing	443779
Easting	48422
Scale factor (point)	0.99
Scale factor (combined)	0.99
[4437795.542,484224.360,1560.(	

Cartesian coordinates	
X	-1280206.568 ± 0.003 m (
Y	-4716804.403 ± 0.006 m (
Z	4086665.484 ± 0.005 m (
[-1280206.568,-4716804.403,408	

“A man with a watch knows what time it is.
A man with two watches is never sure.”

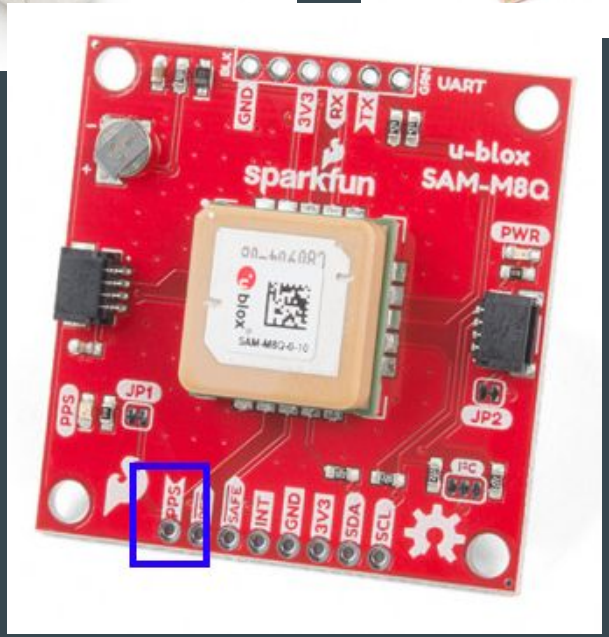
San Diego Union, 1930 a.k.a ‘Segal’s Law’

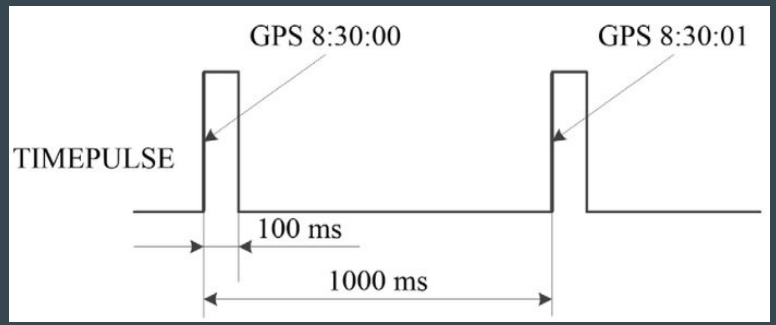
Timebase

- Quartz = 50ppm
- RTC = 2ppm

Timebase

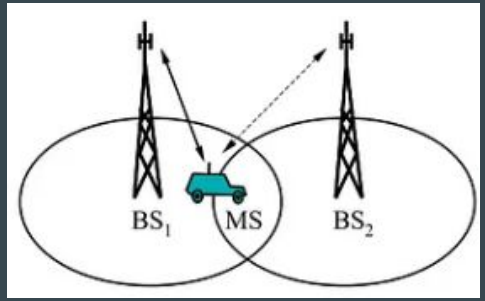
- Quartz = 50ppm
- RTC = 2ppm
- NMEA Time and Date
- Pulse Per Second
- 1ns accuracy = 2000x improvement

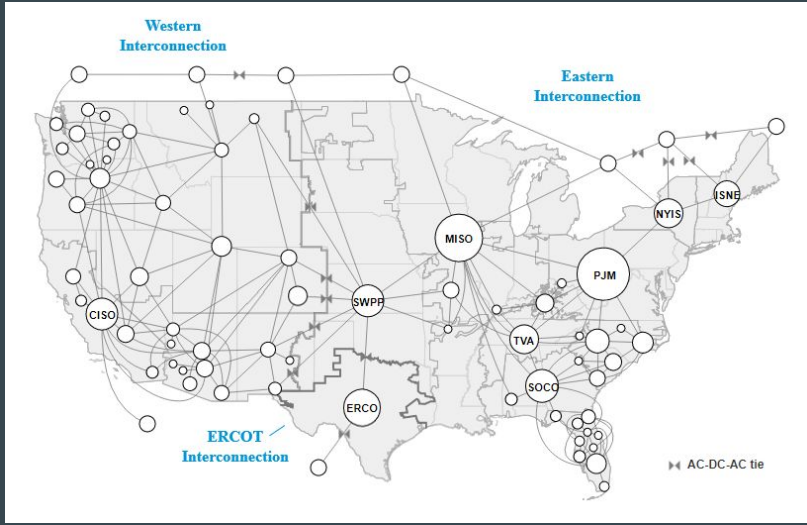


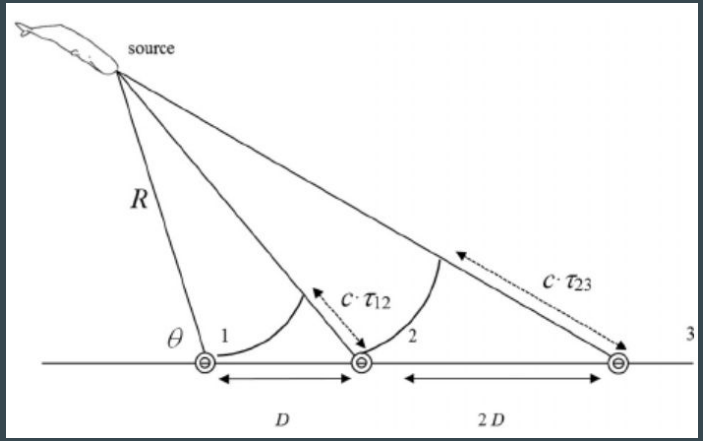


Timing Applications

- Cellular communication
- Wildlife triangulation
- Infrastructure coordination







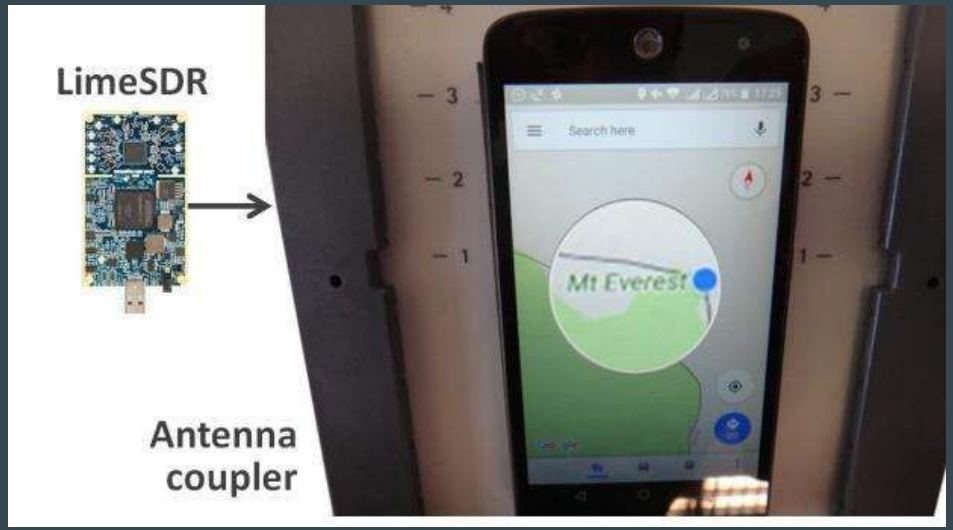
Wild Success

- $1.7 Trillion in economic benefits
- 6.5 Billion receivers worldwide


ATLANTA
JEWISH
FILM
FESTIVAL

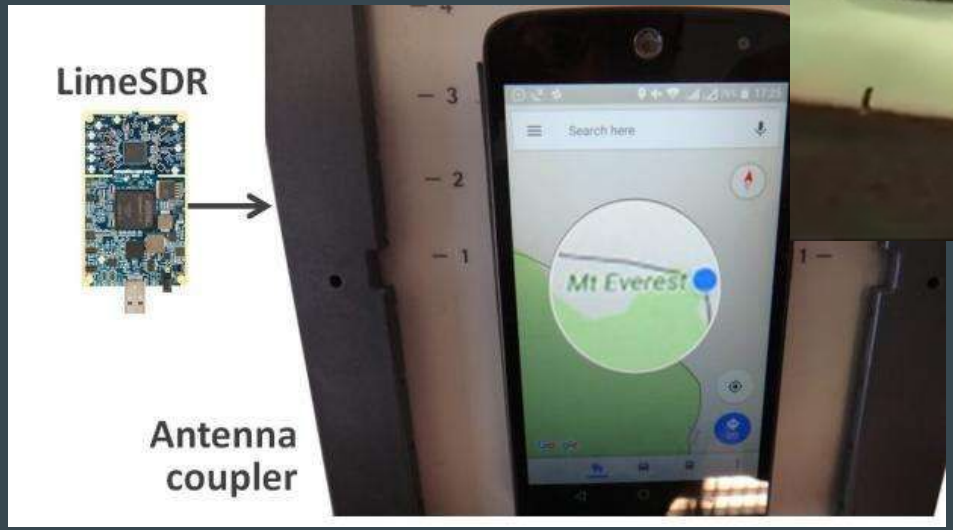
The RQ-170 Incident

- Spoofing = False Signals



The RQ-170 Incident

- Spoofing = False Signals
- 2011 Jamming + Spoofing



The

-
-

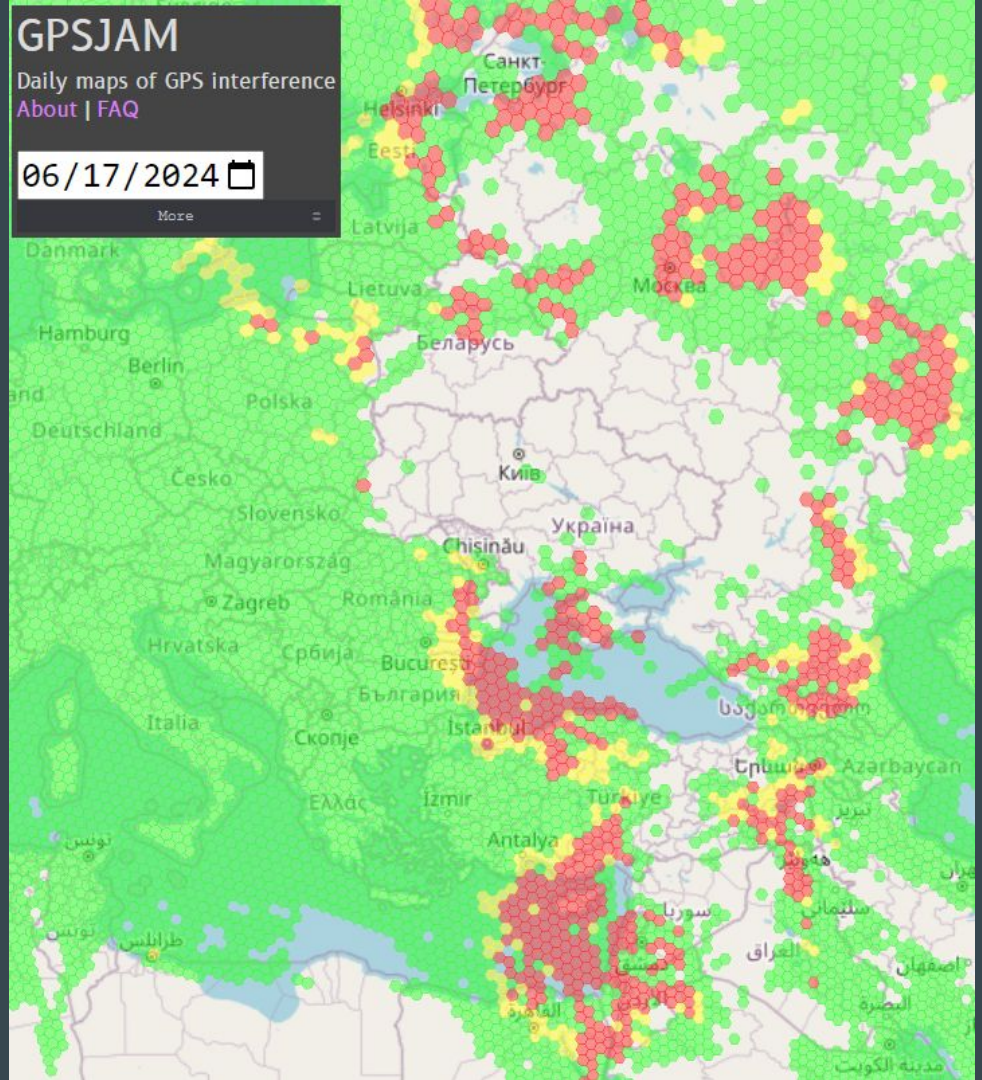
Li

The

-
-

Li

Modern Problem

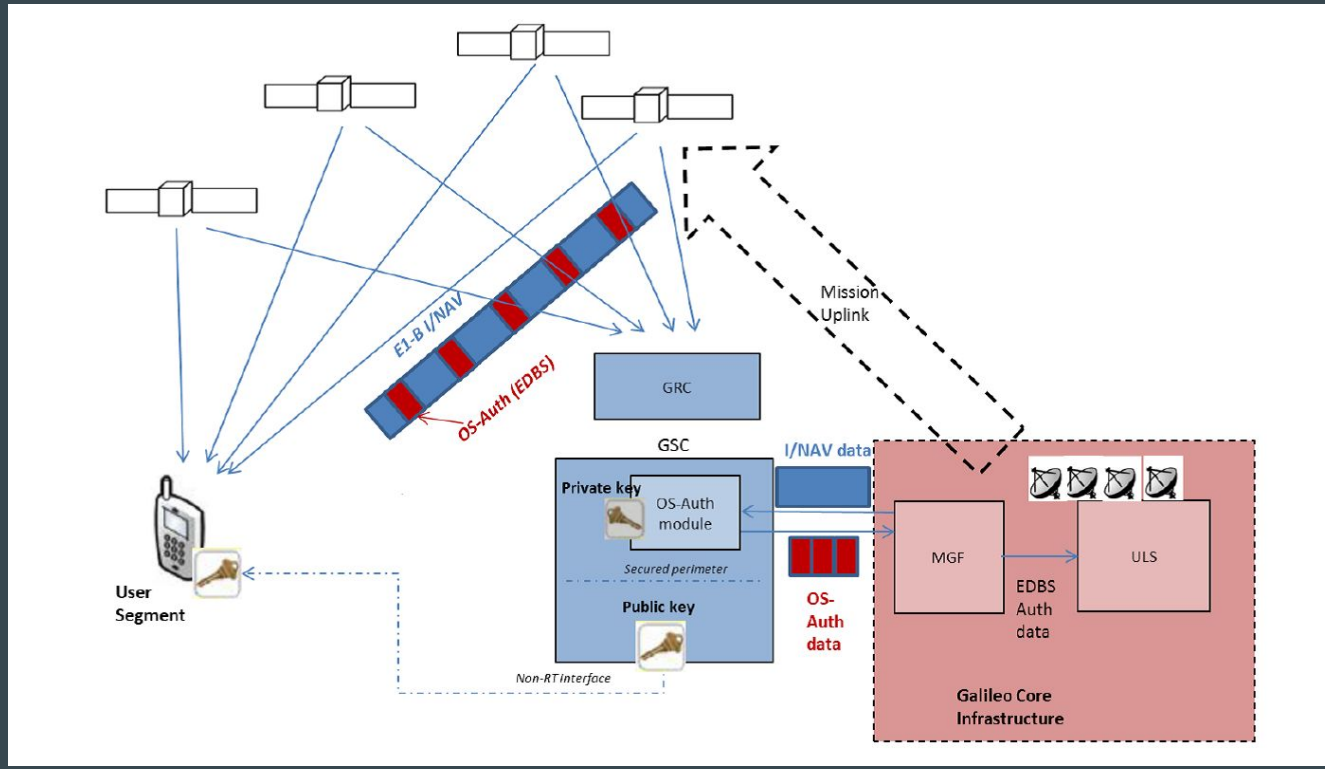


What can we do?

- Spot beams!
- Regional Military Protection Capability

OS-NMA

- Open Service Navigation Message
- Galileo
- Nearly operational



Where am I !?!

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