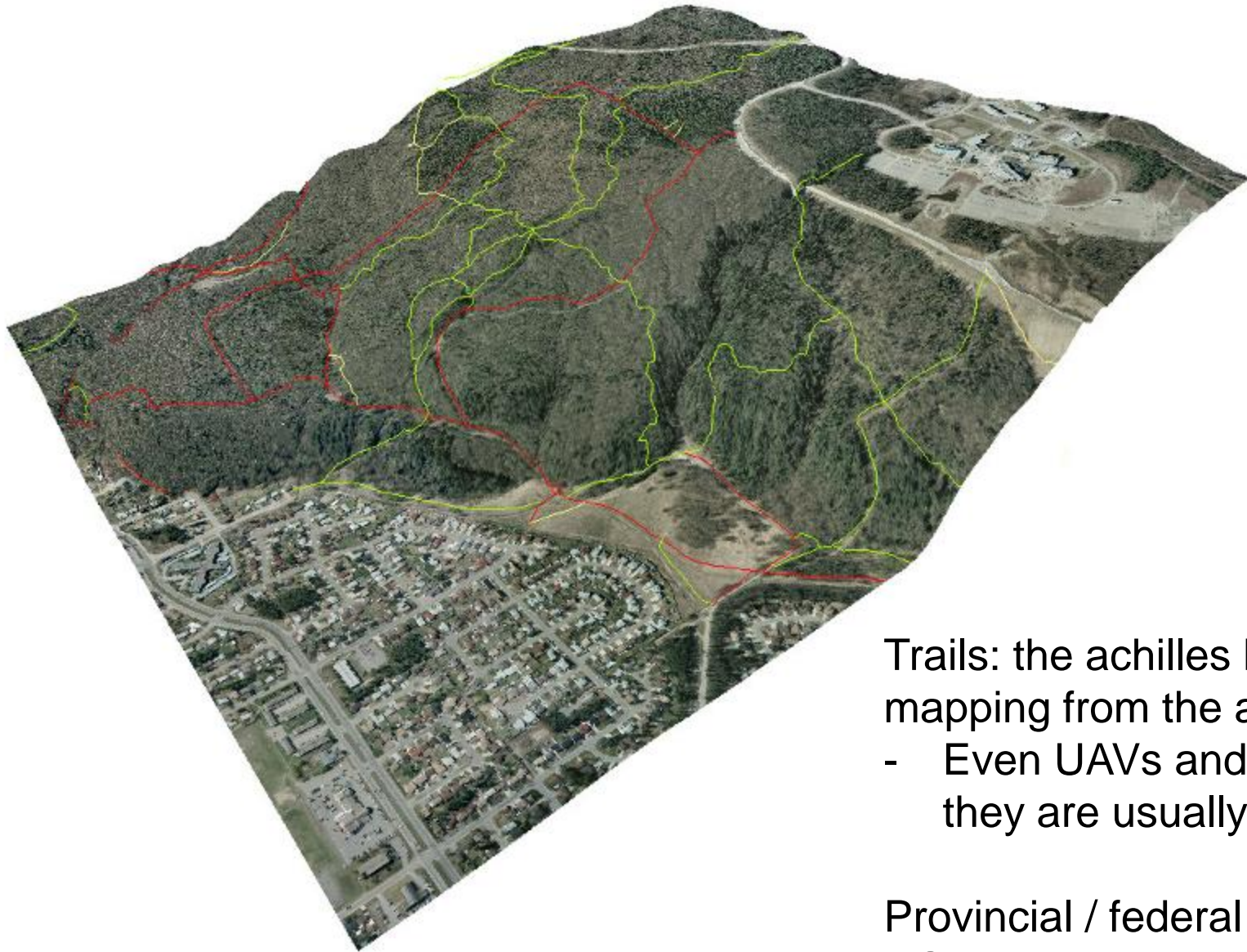


# Global Positioning Systems (GPS)

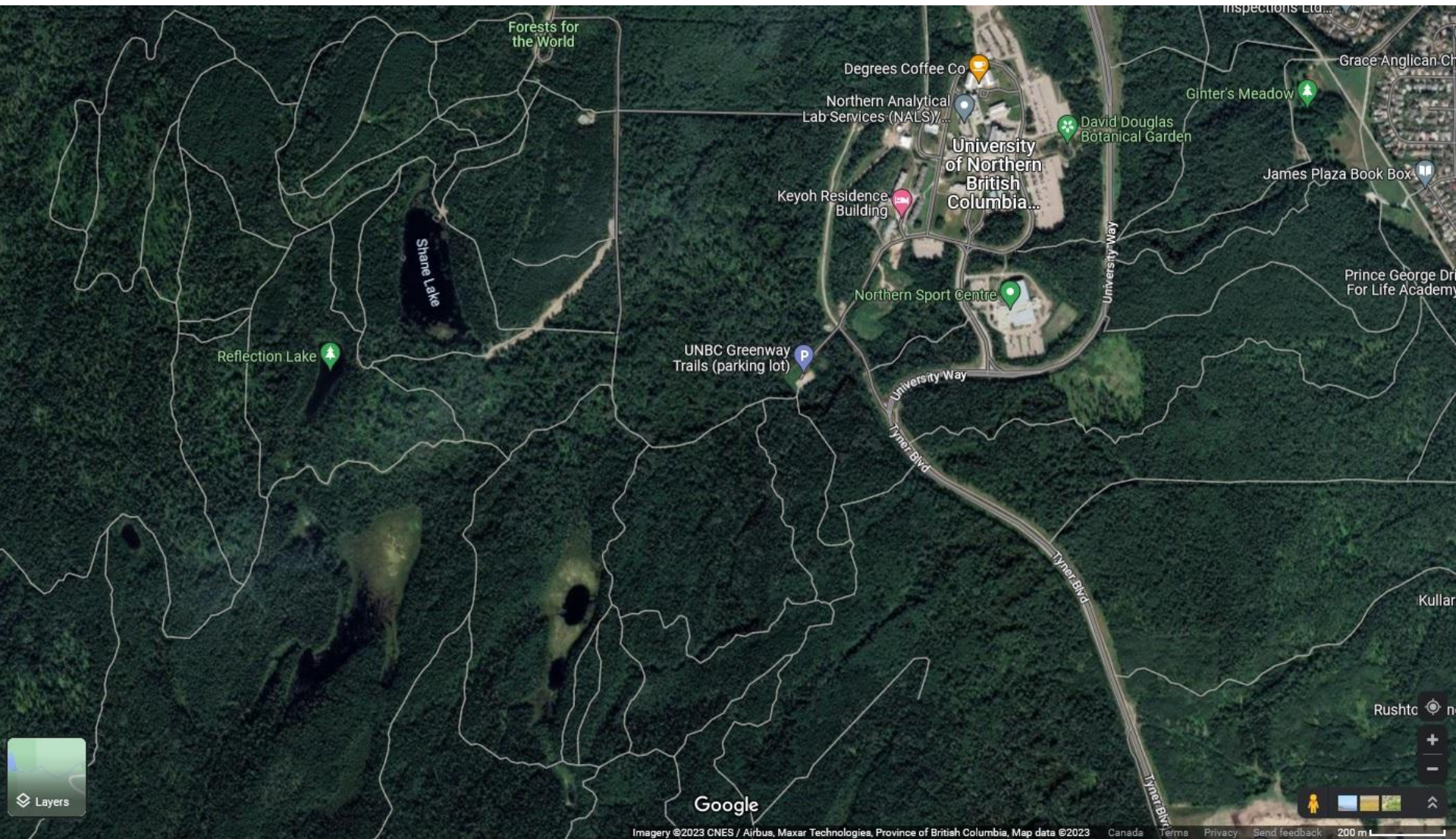


Trails: the achilles heel of mapping from the air / satellites

- Even UAVs and LiDAR as they are usually not visible

Provincial / federal mapping:  
PG trails are from 1982-85

Google maps – updated by citizens with GPS e.g. trails by bikers, general public  
Mostly not surveyed, average accuracy; checked by Google for authenticity



# Mapped and updated by local users using GPS



# Prince George Mountain Biking Trails / city region

Overview Areas Trails Routes Status Reports Photos Videos Events Ride Logs Trail Usage Stats More ▾ Add / Edit ▾

Layers ▾
Basemap ▾
Trail Style ▾
Filter ▾
Activity Type ▾

Popular Routes

- PG Gals N Gears ...
- May 2020 PGCC S...
- Otway Relay 2021
- Jaymee/Juno

LEGEND

3 km

- Trails
- 10 Dollar
- 147
- 50 Shades
- AC/DC
- Adams
- Alaskan Pipeline
- Alternate trail
- Artwork
- Artwork Lookout...
- Artwork North

No description for Prince George has been added yet! Login or register to submit one.

Activities [Click to view](#)

Mountain Bike	E-Bike	Hike	Trail Running
302 trails	42 trails	286 trails	283 trails
ATV/ORV/OHV	Snowshoe	Nordic Ski	
8 trails	46 trails	24 trails	

<https://www.trailforks.com/region/prince-george>

# GPS applications – polygons

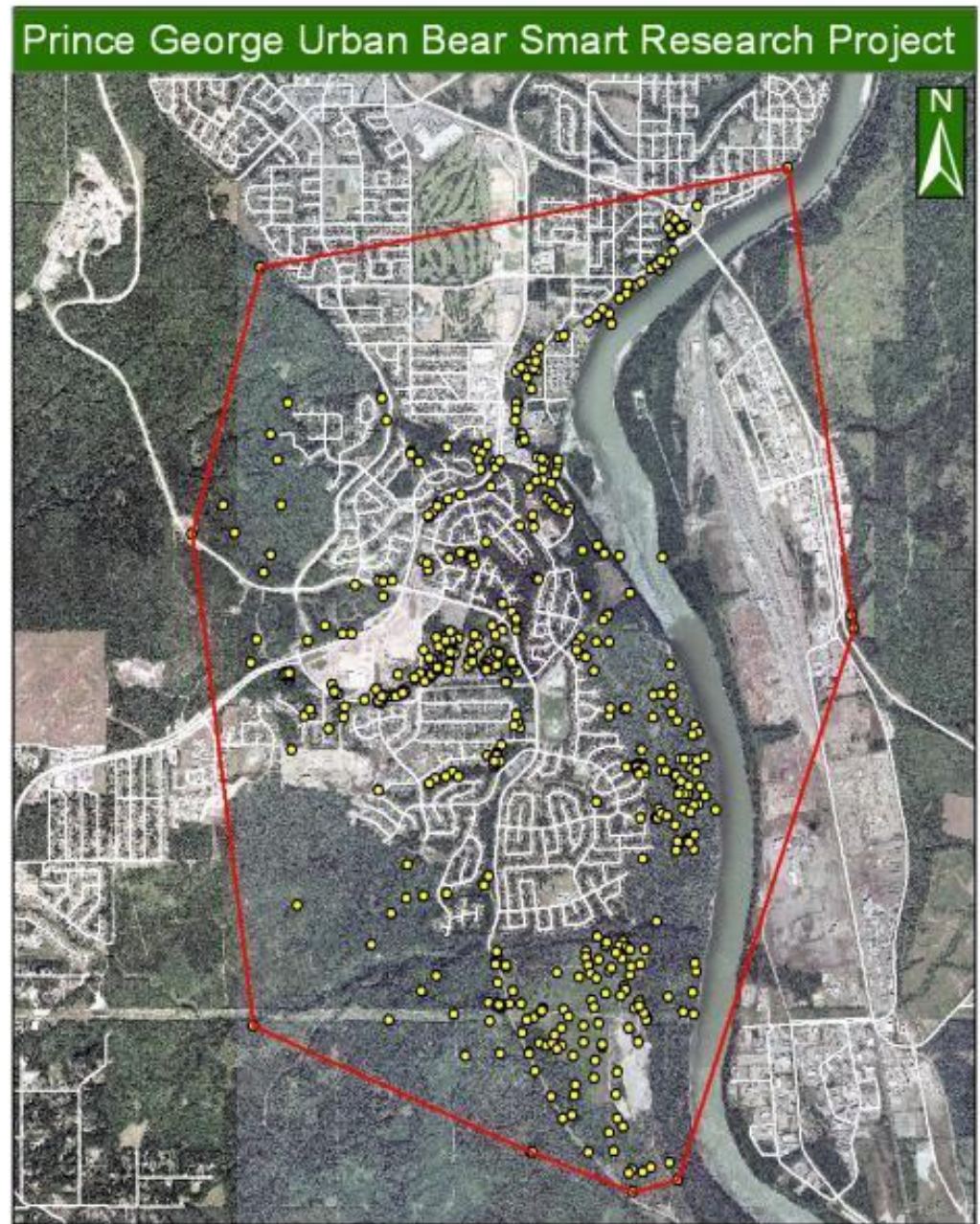


Higher accuracy required than in recreational mapping

# Northern Bear Awareness Society

GPS wildlife collars  
- point collection

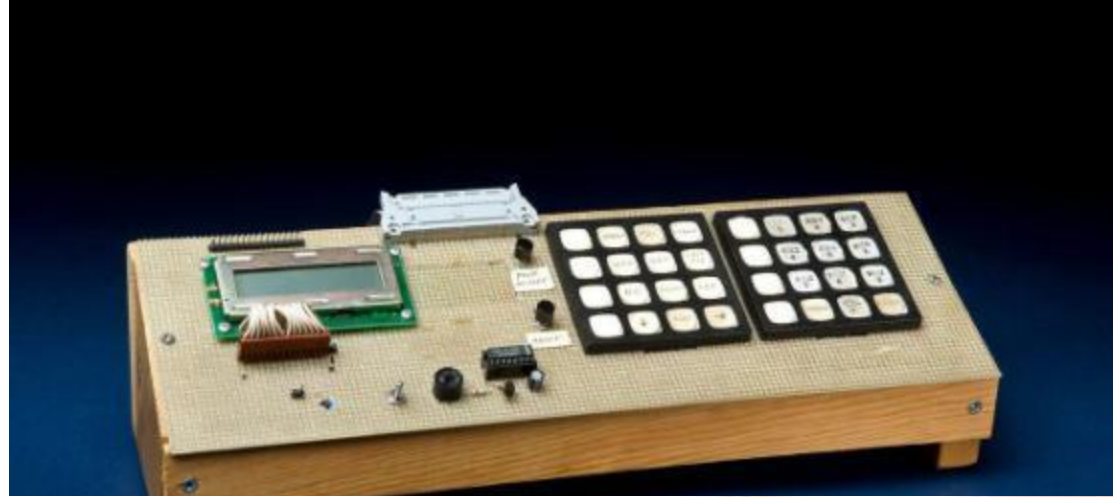
- monitor movements to  
minimise conflicts between  
predictable bears and  
unpredictable humans



# Global Positioning Systems – GPS

- **How much do we need to know ?**
- **Turn it on, it gives your position ?**
- **You move, the position changes**
- **You don't move, the position changes - what ?**
- **Easily Download/upload GPS data for mapping e.g. .gpx**

# GPS in the 1980s





# What is GPS ?

The **Global Positioning System (GPS)** is a satellite system that provides locations anywhere on Earth where there is a clear line of sight to **four** or more GPS satellites. (wikipedia)

Satellites launched 1978->  
System 'first operational' 1989

list of satellites:

[http://en.wikipedia.org/wiki/List\\_of\\_GPS\\_satellites](http://en.wikipedia.org/wiki/List_of_GPS_satellites)

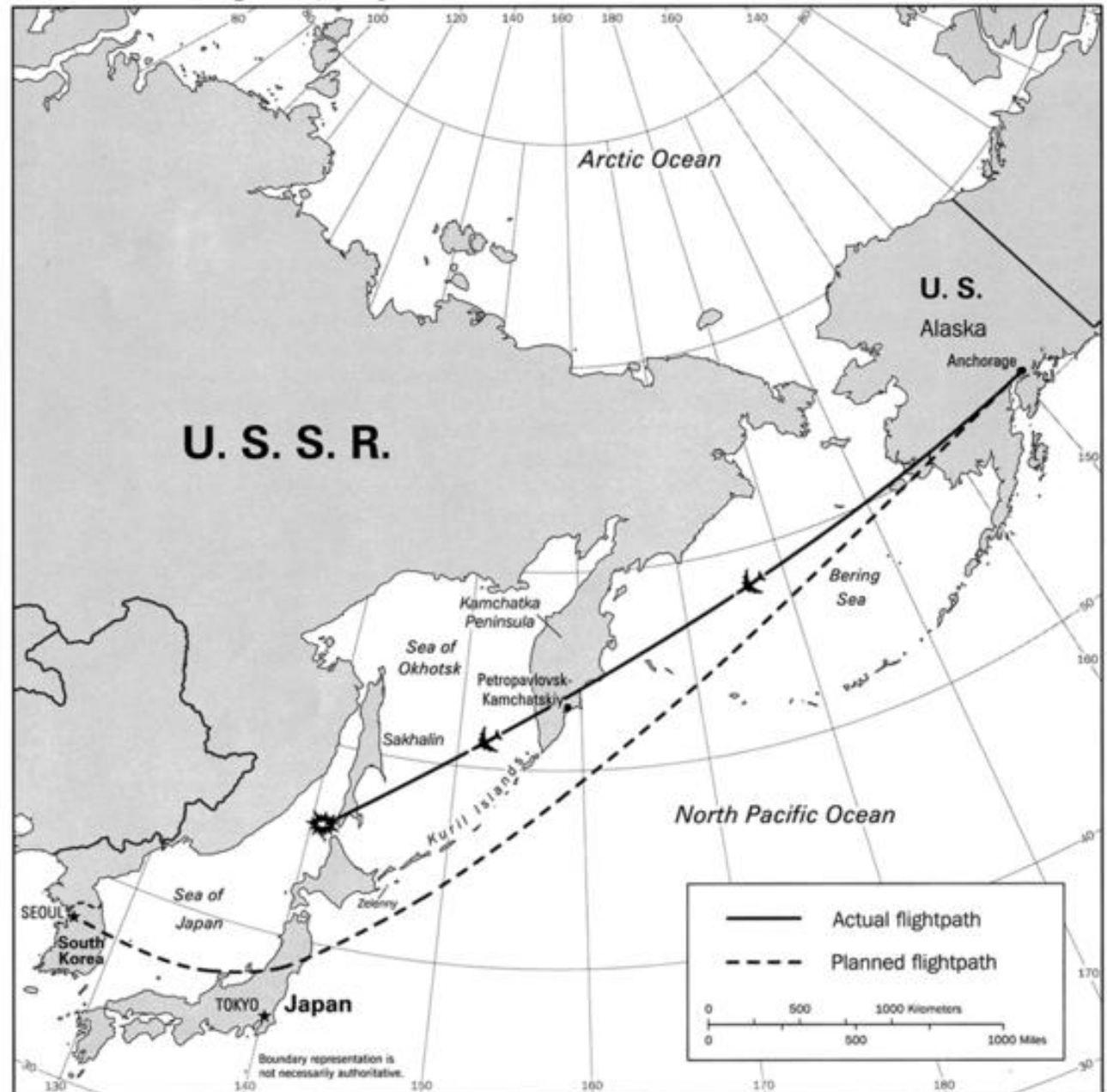
# Satellites launched 1978- >

KAL 007: 269 killed

1983 President  
Reagan insists  
civilians must have  
GPS technology  
when it is ready

Initially designed to  
pinpoint locations  
and also reduce  
civilian casualties

Korean Airlines Flight 007, 1 September 1983



# The Global Positioning System (GPS)

-> Global Navigation Satellite System (GNSS)

... a satellite-based navigation system consisting of a network of 24 orbiting satellites that transmit radio signals to GPS receivers (fully operational 1995)

The system consist of 3 'segments':

- Space segment
- Control segment
- User segment



# 1. Space segment: Satellite Constellation

GPS is the USA system (1978)

Russia - GLONASS (1982)  
Operational by 1995, Restored in 2011

Europe - Galileo (2011)  
China - BeiDou (2012)

See animation:

[https://en.wikipedia.org/wiki/Global\\_Positioning\\_System](https://en.wikipedia.org/wiki/Global_Positioning_System)

Also some regional systems e.g India (IRNSS)

GPS: 24 satellites at 20,000 km altitude, at  $55^\circ$  angle to equator

(Galileo is at 56 degrees, Glonass is at 65 degrees)



## 2. Control segment: ground stations

These 5 stations monitor the GPS satellites, check their operational health and exact position in space. The master station transmits corrections for the satellite's orbit and clock offsets back to the satellites



# Ascension Island



# Diego Garcia



In 1971, 2000 inhabitants were forcibly removed from **Diego Garcia** to Mauritius to enable a US military base; 1000 pet dogs gassed in a warehouse  
Islanders were later denied compensation in 2003 by the Blair government

<http://www.guardian.co.uk/politics/2004/oct/02/foreignpolicy.comment>

<https://www.bbc.com/news/uk-48426031> ..... descendants feel like 'lost nation'

### 3. User segment: GPS receivers with relative accuracy

a. Handheld recreation units  
e.g. Smartphones  
\$200

5-10m



b. Resource/map grade units  
\$2000

1-5 m



c. Survey grade units  
\$10,000

1mm - 1m



True accuracy relies on several factors - see below

# Pre-GPS surveying: identification of point locations by Survey triangulation (3 points/angles)

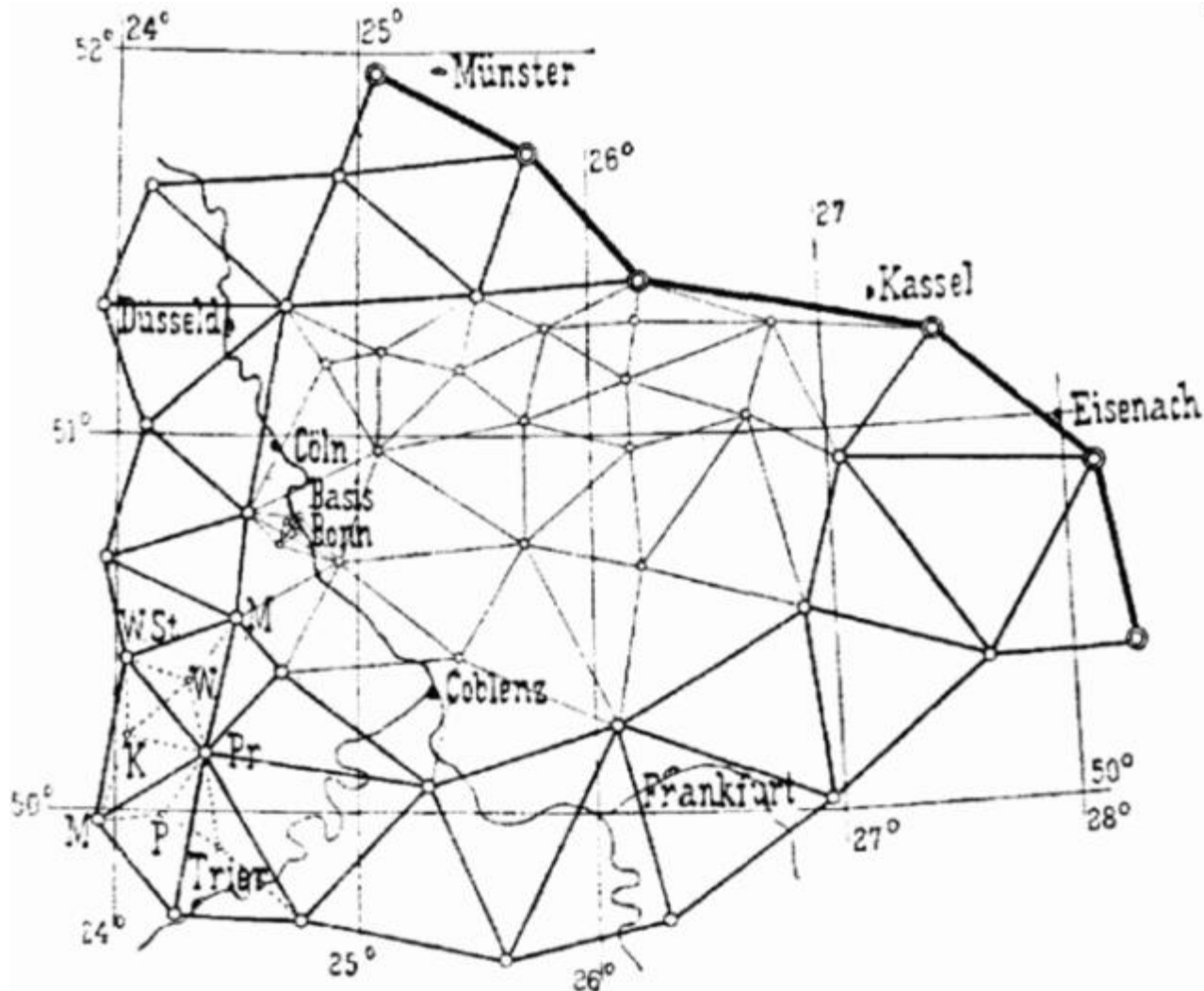
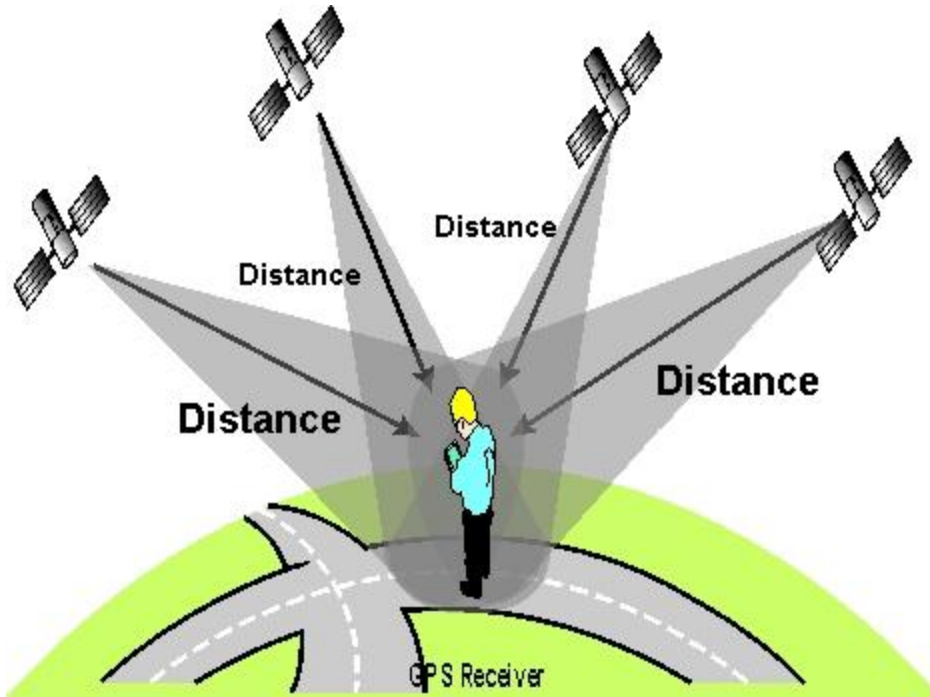


Fig. 4. Die rheinisch-hessische Kette und das nieder-rheinische Dreiecksnetz.



# GPS Trilateration



Code is transmitted many thousand times a second and includes

- Time
- Which satellite it is
- XYZ coordinates (ephemeris)

$$\text{Distance} = \text{Time} \times \text{Speed}$$

(Speed = 300,000 km/sec)

Atomic clocks measure time in seconds to 10 decimal places

GPS units receives code at time plus travel time (decimal seconds)

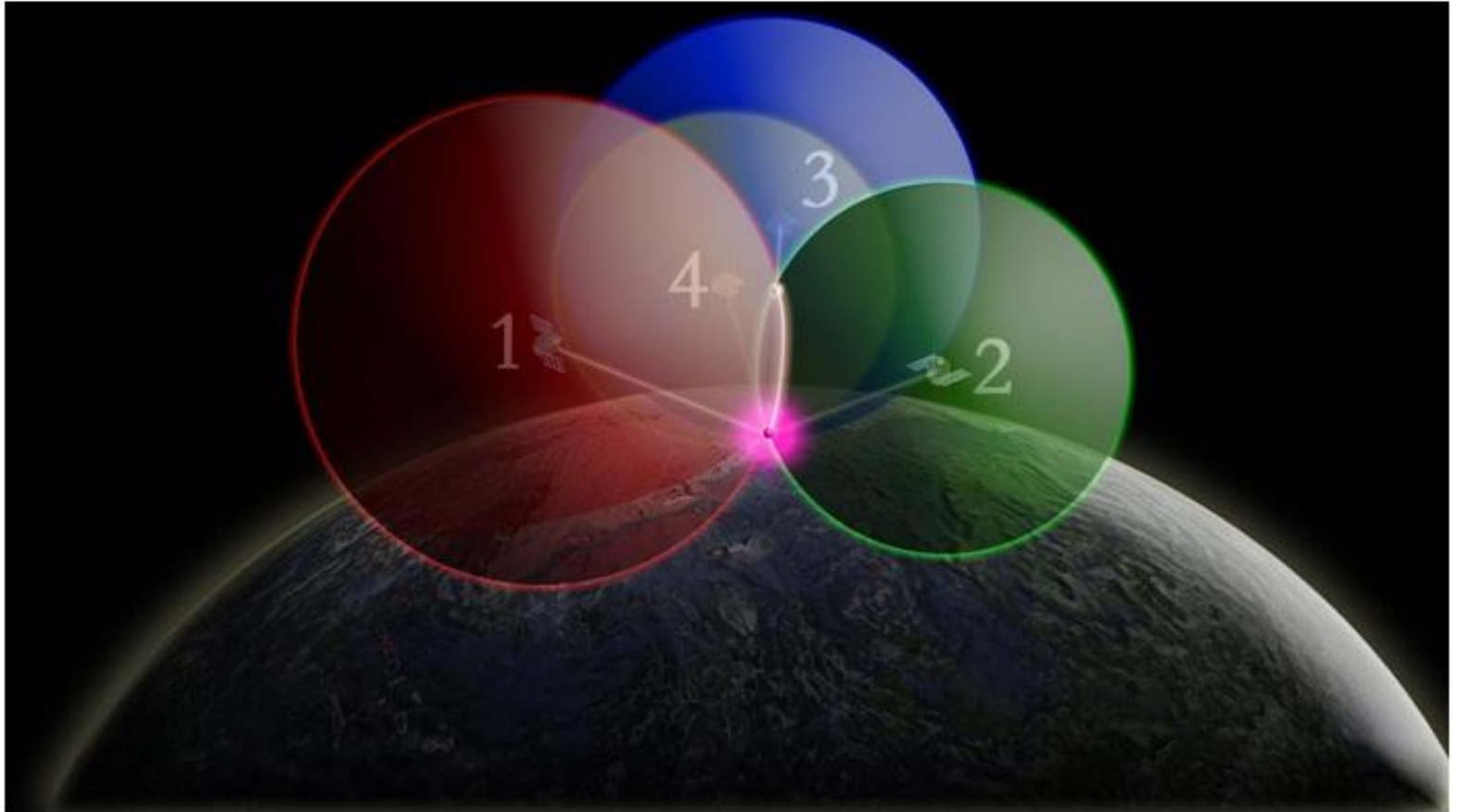
The delay or lag when the GPS receives it is the signal's travel time.

GPS unit multiplies the time by the speed of light to determine how far signal travelled from satellite

Software combines the > 4 readings to generate a ground location

Solves for x, y, z and 'time'  
- uncertainty of ground clock

## GPS satellites and positioning: four satellites

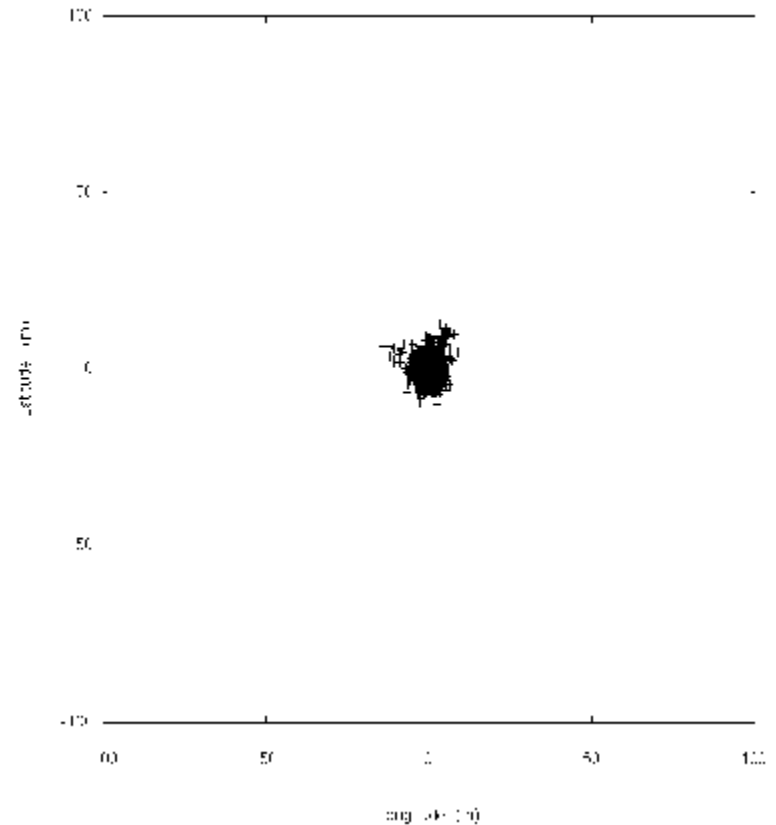
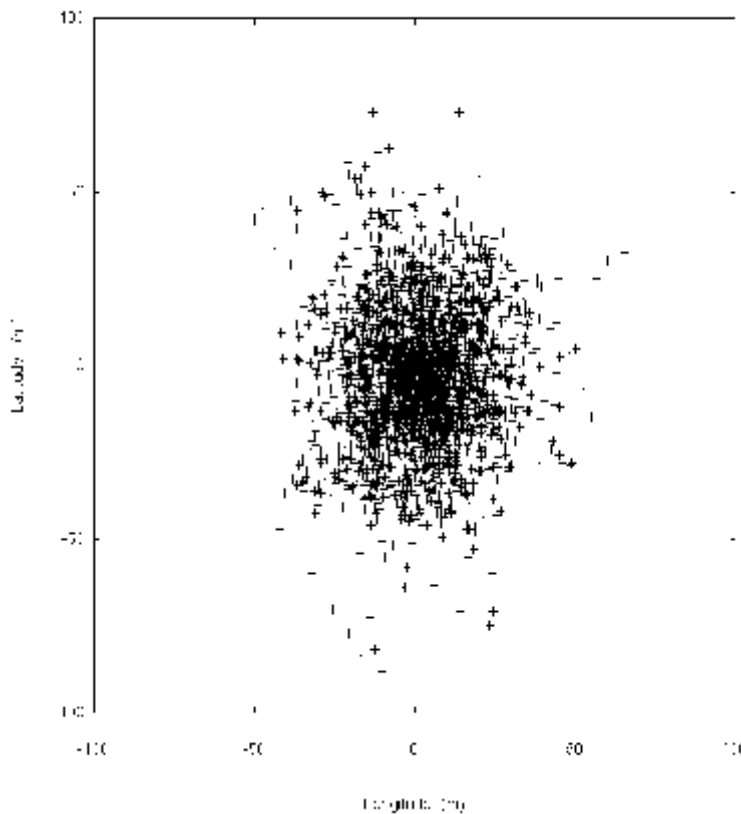


# GPS terms: 1. Selective Availability (SA)

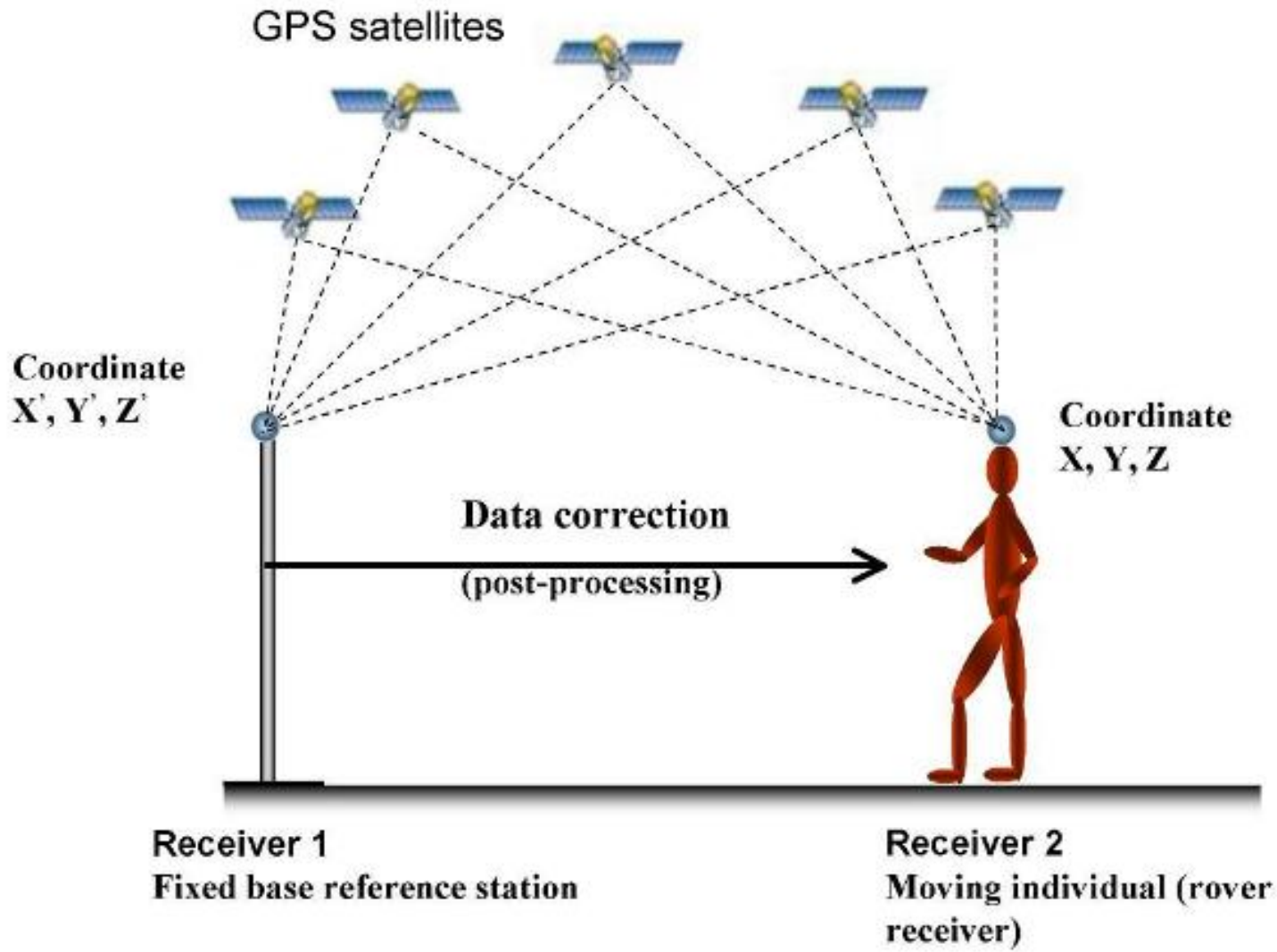
- Random error, added to GPS signals before 2000
- .. up to **100 metres** error by scrambling last 3 decimals of time signal
- Turned off May 1, 2000 at midnight; No intent to ever use it again
- e.g. Time = 3.1234567890 = 3.1234567000

May 1, 2000 - Selective Availability on

May 3, 2000 - Selective Availability Off



## 2. Differential Correction (DGPS) -industry solved SA problem



**Base station, Coast Mountains, Mt. Waddington - real-time DGPS**



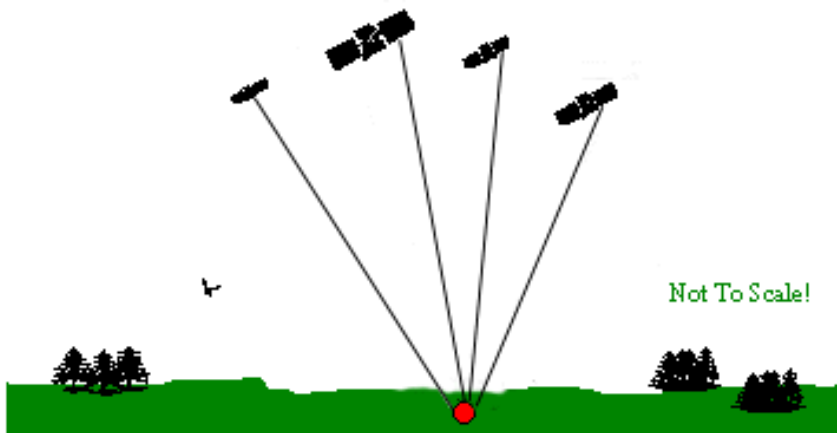
# 3. (Percent) Dilution of Precision

- PDOP is an indicator of the quality of the geometry of the satellites
- Well spread out, and not too low in the sky

BC standard: PDOP < 8.0 acceptable

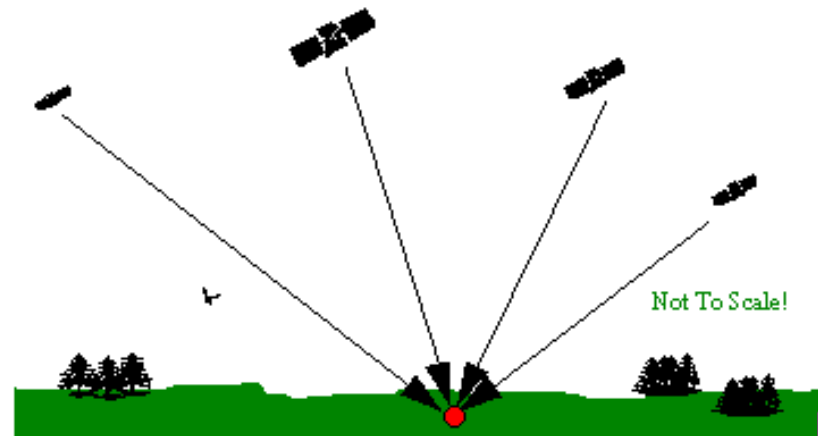
PDOP < 4.0 : excellent

Poor Dilution of Precision



High DOP (poor)

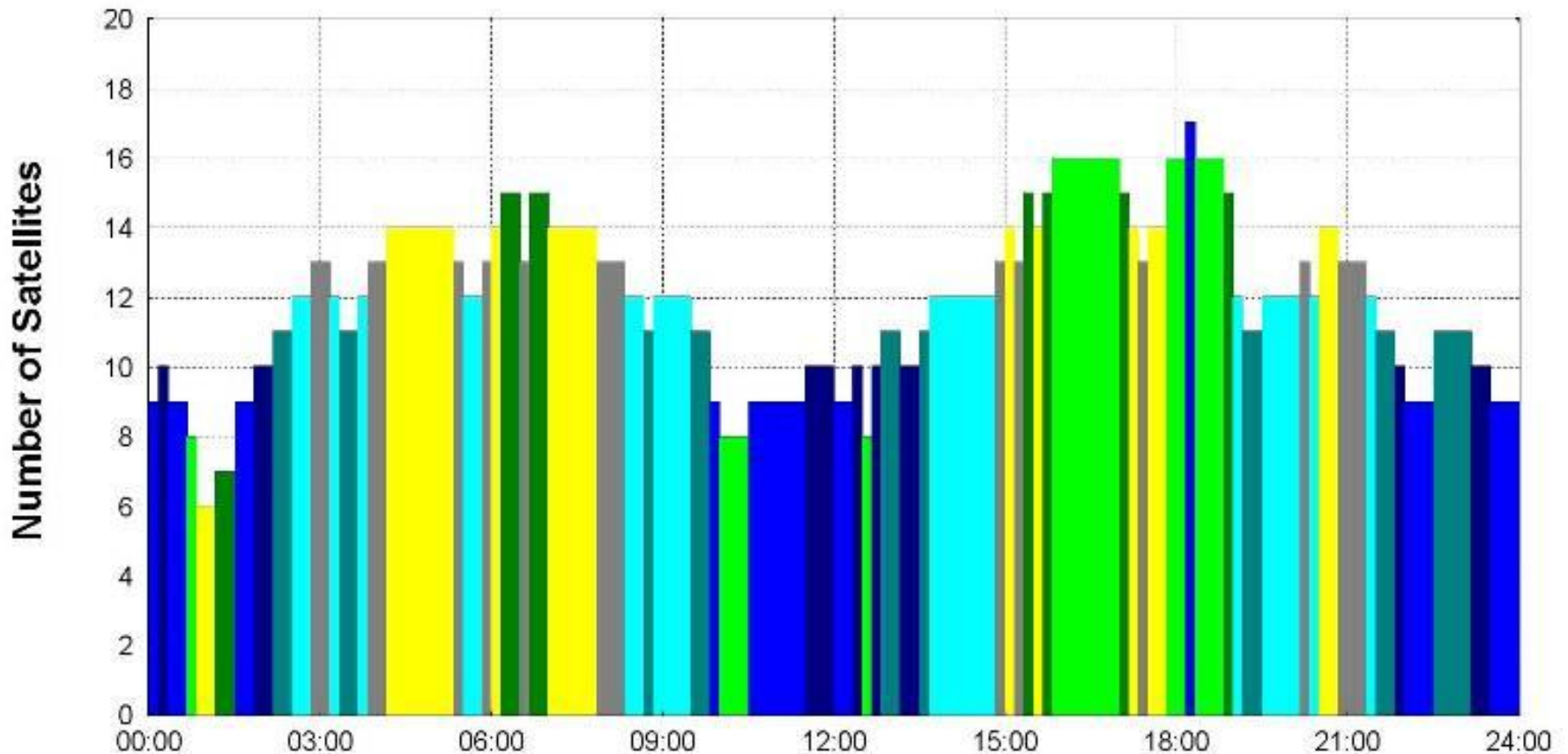
Good Dilution of Precision



Low DOP (good)

# # of satellites (affects PDOP)

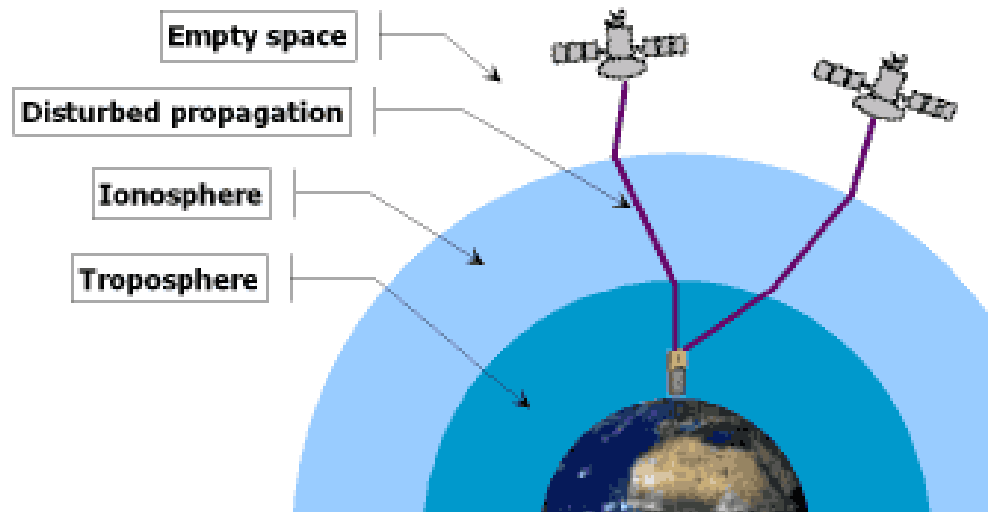
## Visibility



# What are the remaining sources of error? (after SA removed and good PDOP)

## Potential Error

Ionosphere	4.0 metres
Clock	2.1 m
Ephemeris	2.1 m
Troposphere	0.7 m
Receiver	0.5 m
Multipath	1.0 m
<b>Total</b>	<b>10.4 m</b>



This is why your reading can change even when you don't move

We use DGPS to help remove these errors ...

Uncorrected GPS ~10m  
Corrected (DGPS) ~1m

You can reduce error by taking the average of many readings e.g. at trail junctions



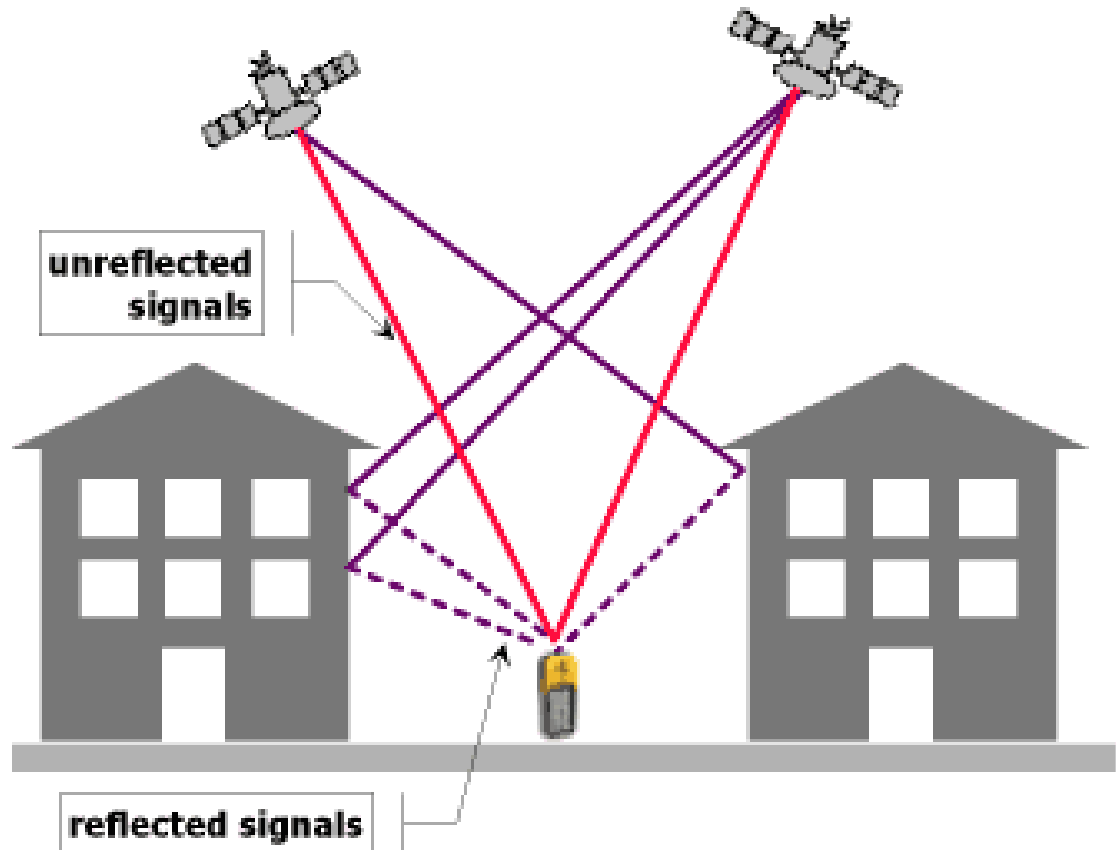
# GPS track on Cranbrook Hill – out and back same trail, iPhone

**Error: ~ average 5 metres**

10m



# Multipath: GPS is line of sight



In the way: e.g. buildings, mountains, solid tree canopy ..

# High latitude, E-W valleys, e.g. Norway

the valley sides may block good GPS reception ...



# Environmental Factors ?

- Generally, GPS is unaffected by weather
- But heavy rain can weaken the signal
- Wet foliage deflects more than dry foliage
- General Humidity and Temperature - no effect
- Wind may have positive effect under forest canopy

**iPhone v** handheld GPS: advantages: better maps/software, larger screen, cheaper  
Advantages of handheld GPS: longer battery life, higher precision, more rugged



Jackie O'Neil, BGISc, University of Regina (2017)

# Data quality: Spatial generalization, accuracy and precision: GPS and GIS

## Trailhead

Johnston Canyon Resort, 17.5 km (11 mi) northwest along the Bow Valley Parkway from the Trans-Canada Hwy.

## GPS Coordinates

Latitude: 51.24542307241623

Longitude: -115.83992958068848

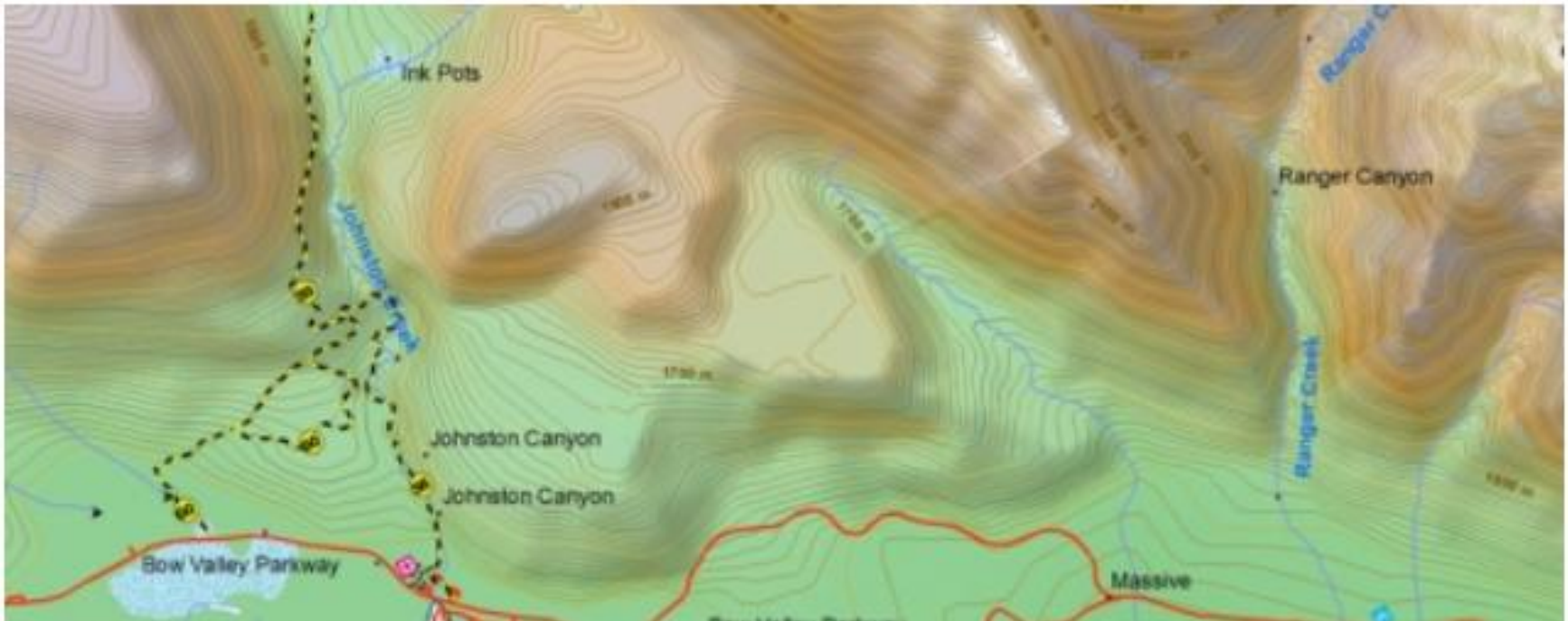
14 decimal places !

-too precise; NOT accurate

-not enough **generalization**

Last digit = millionths of a mm

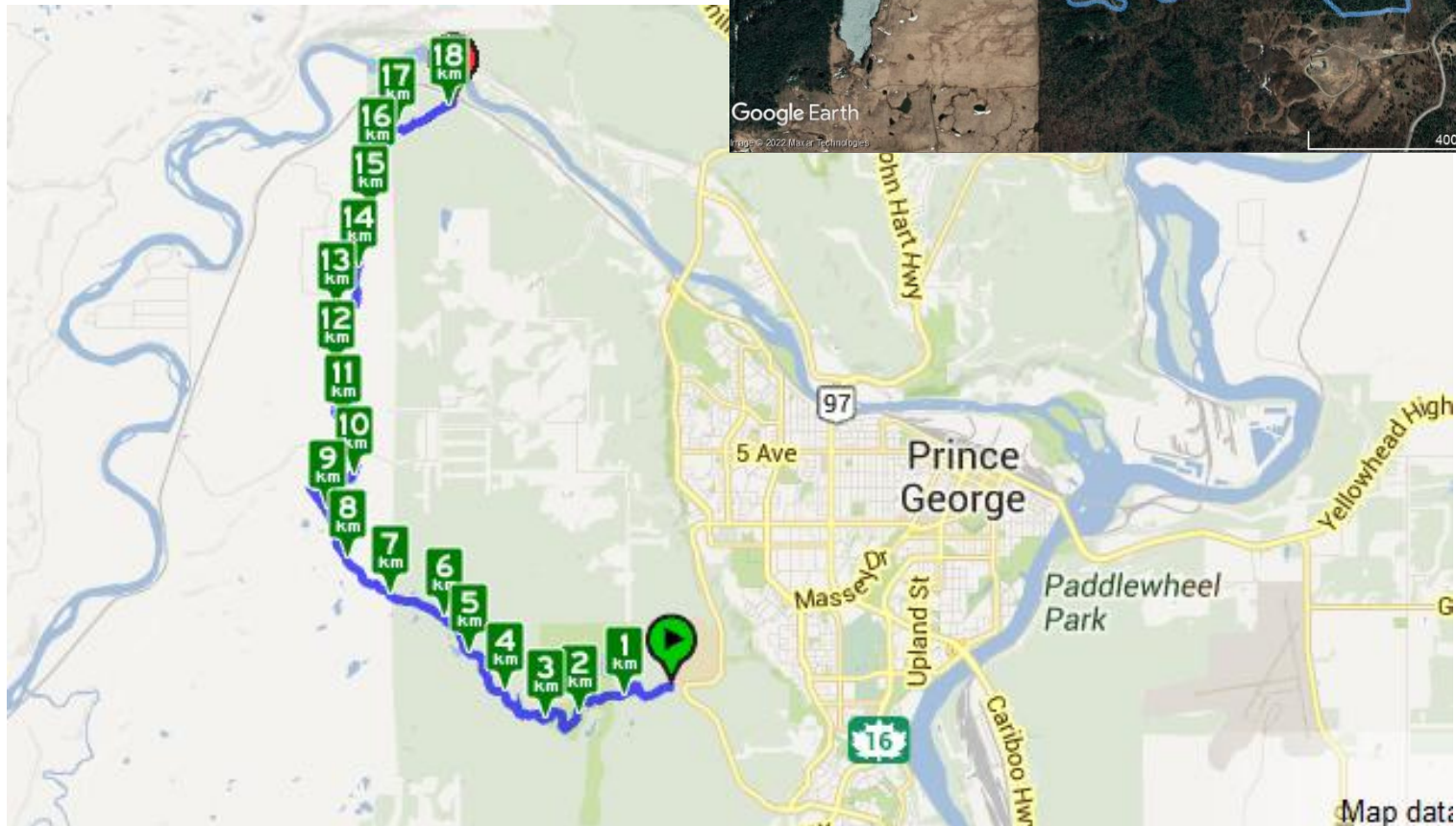
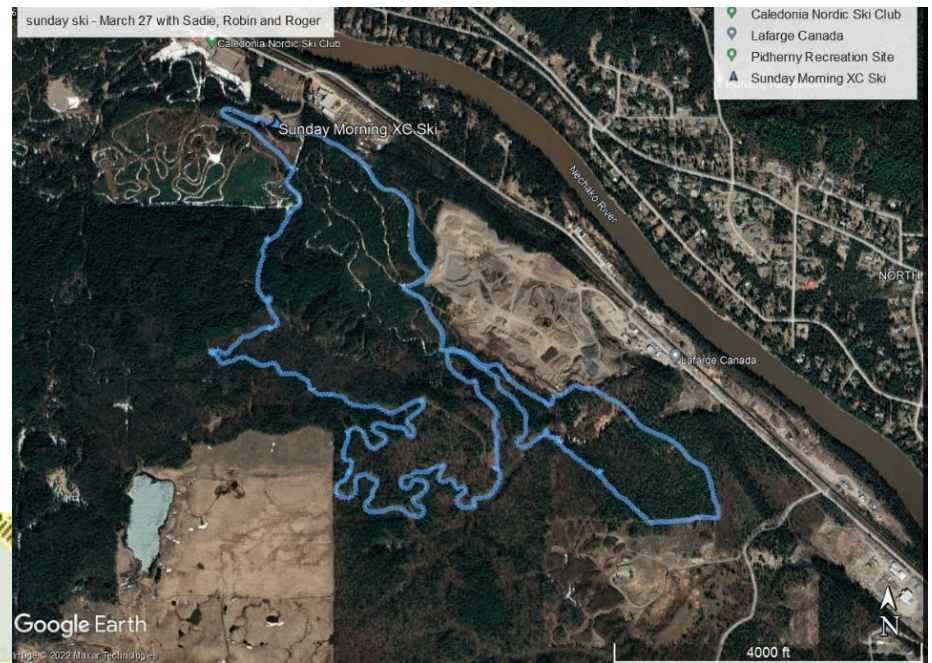
## Detailed Map



# GPS data input:

<http://www.mapmyrun.com>

<https://www.geocaching.com>



Yasushi Takahashi traveled across Japan with a GPS to create a 7,163-km drawing to propose to his girlfriend. It's certified as World's largest GPS drawing.

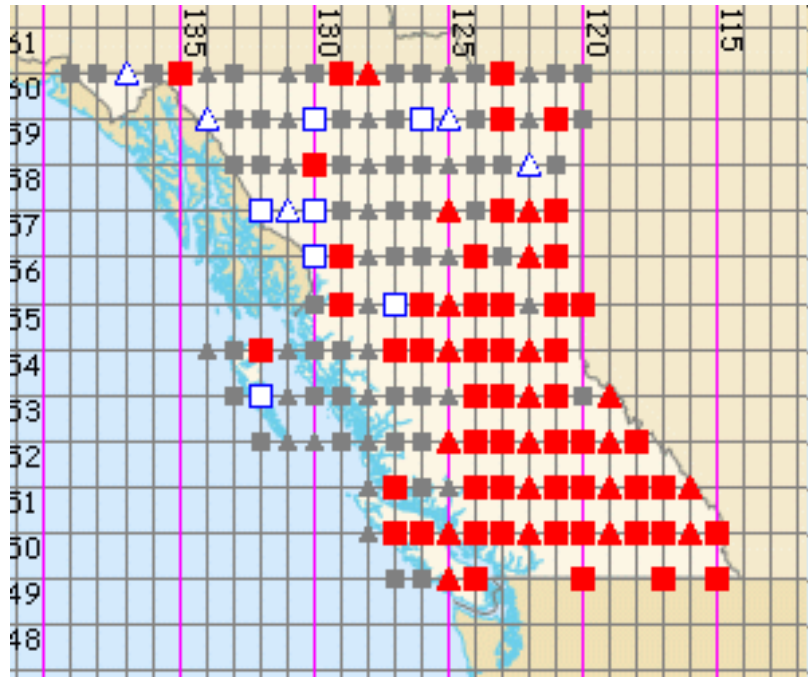


‘結婚してください’



Screengrab from video uploaded on YouTube by Google





54N, 124W: 1.8 km (1.1 miles) SSE of Vanderhoof, BC, altitude: 695 m (2280 ft)



Public mapping every degree intersection:

<http://confluence.org>