Navigation for exploration robots traveling long distances

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Overview

- Brief History
- Telling Time
- Trilateration
- GPS
- Star Tracking
- Modern Systems
- Modern Research
- Citations

Brief History: How Far We've Come

- Latitude
- Longitude Problem
- Dead Reckoning
- Longitude Act 1714
- Port Of Origin Time
- John Harrison 1759
- Sputnik 1957
- TRANSIT 1964
- TIMATION 1967
- GPS/NAVSTAR 1973
- WAAS 1994
- First successful WAAS Flight 2003

Exercise

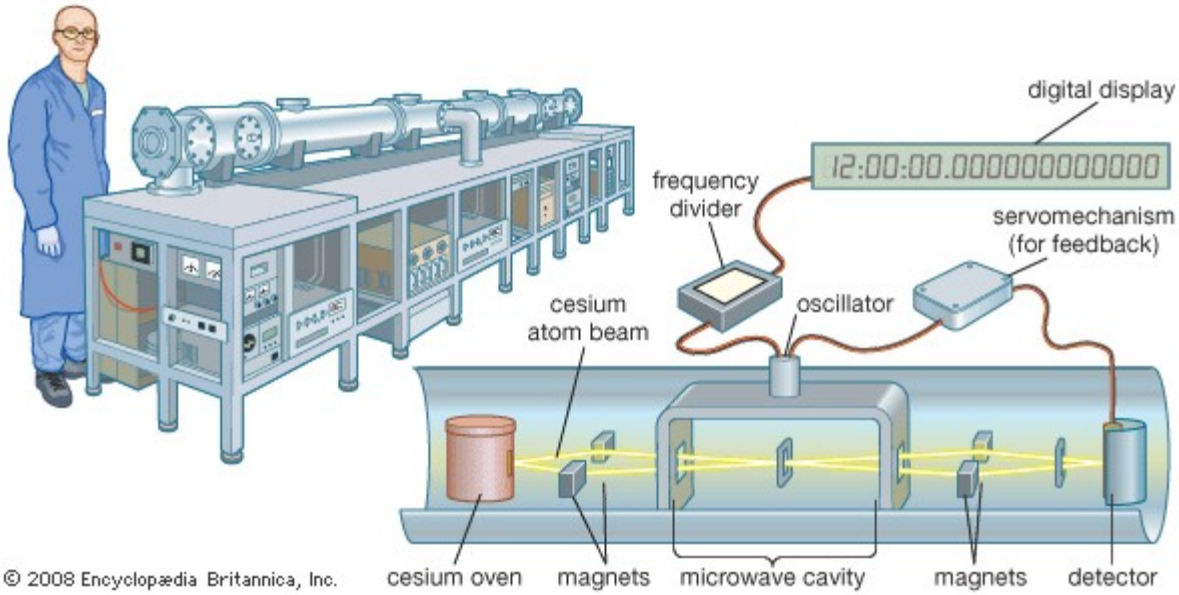
- Lets suppose that you are sitting on a boat that is anchored out in the middle of the ocean and all you have is a chronometer and a sundial. The Chronometer tells you that it is 6 AM in England at the prime meridian. The sundial tells you that its about 11 AM where you are. Can you tell me what your latitude and longitude are? Later that evening you measure the angle between the north star and the line tangent to the earth. It is 45 degrees. Can you tell me your longitude and latitude now?

Telling Time

- **What is a Second Officially?**
  - The interval of time taken to complete 9,192,631,770 oscillations by a cesium atom exposed to suitable excitation

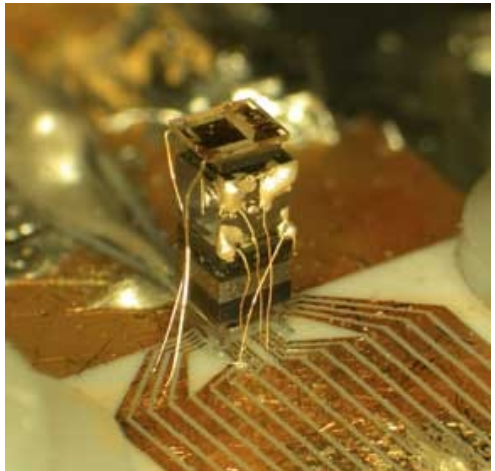
Telling Time

- Atomic Clocks
- Cesium,rubidium, hydrogen (Galileo)

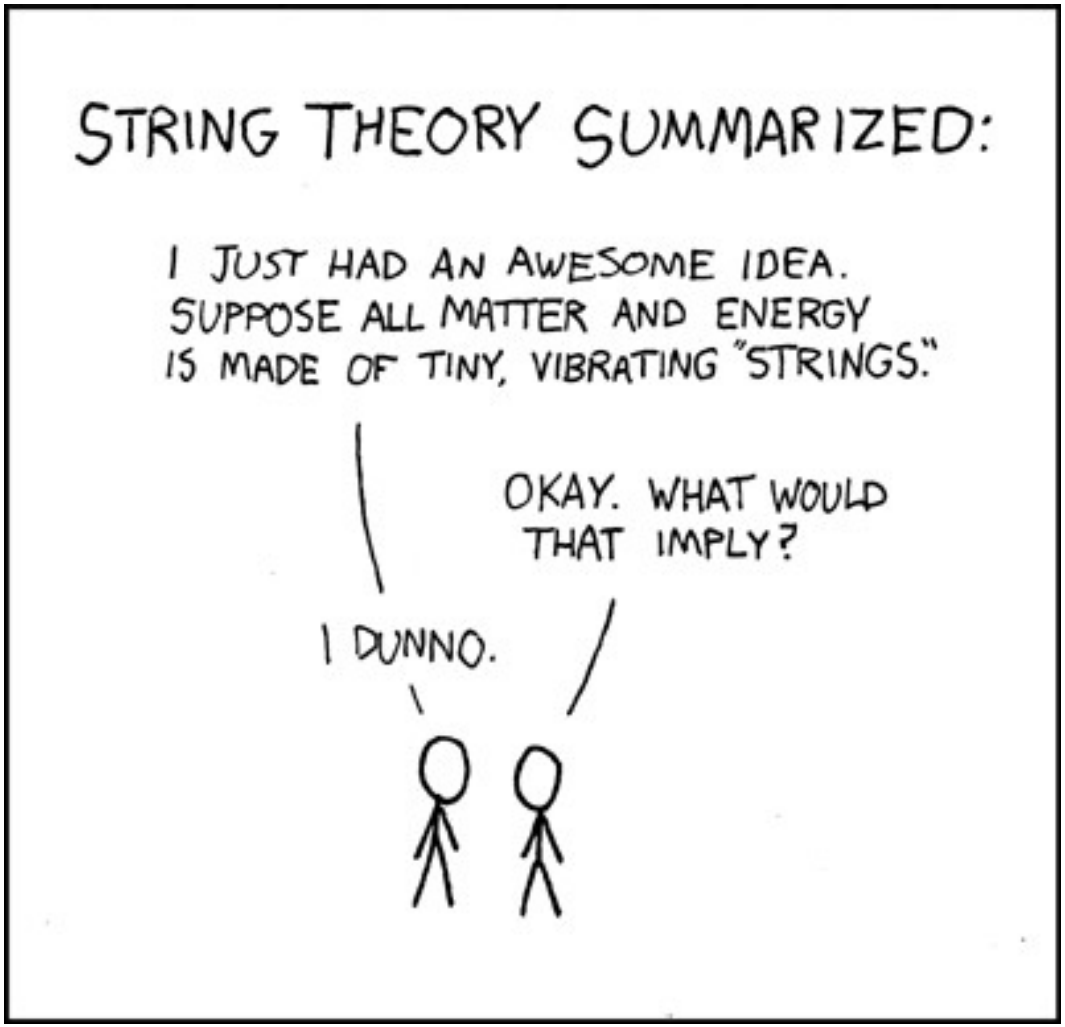


Telling Time: Where can I get it?

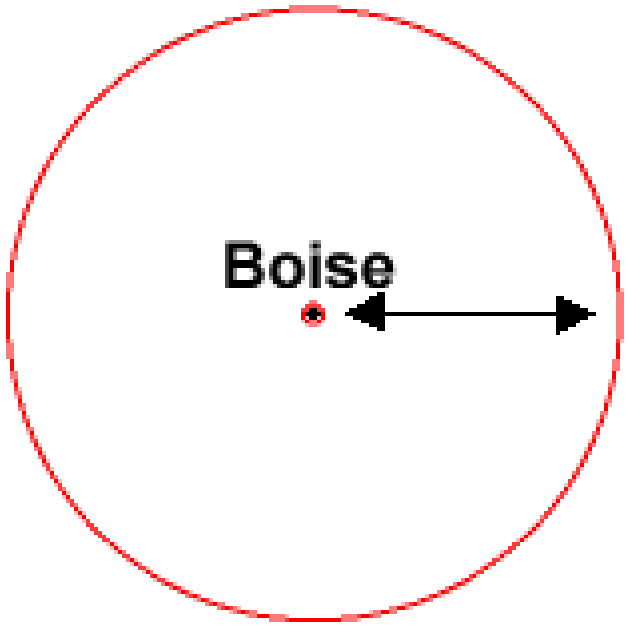
- **Oldest Service: Radio Station WWV, near Fort Collins Colorado transmits at 2.5, 5, 10, 15, and 20 megahertz.**
- **www.time.gov**
- **Software for computer synchronization www.bldrdoc.gov/timefreq/service/nts.htm**
- **NIST makes a version whose volume is < 10 mm^3**
- **12 dollar wall clock that syncs with time.gov**
- **Chip-Scale Atomic Clocks**
- **Current GPS satellites carry 2 cesium and 2 rubidium Clocks**
- **Atomic clocks can cost in excess of $100,000**



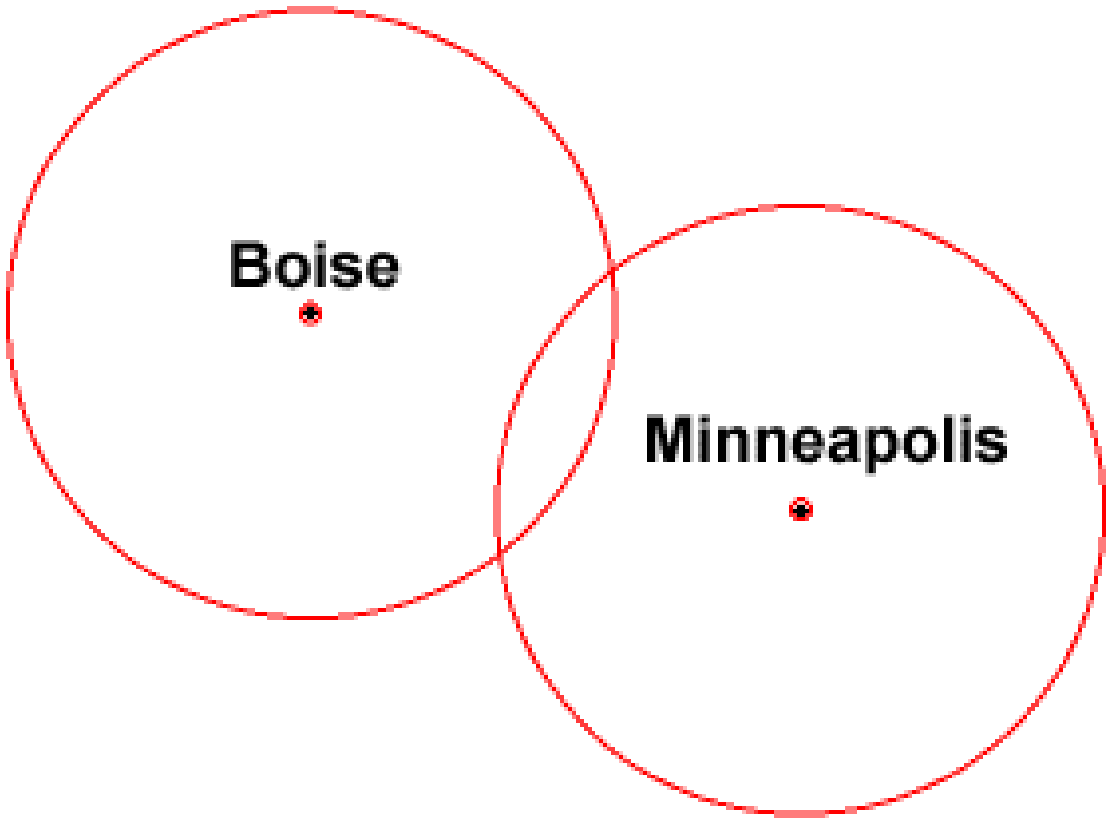
Trilateration



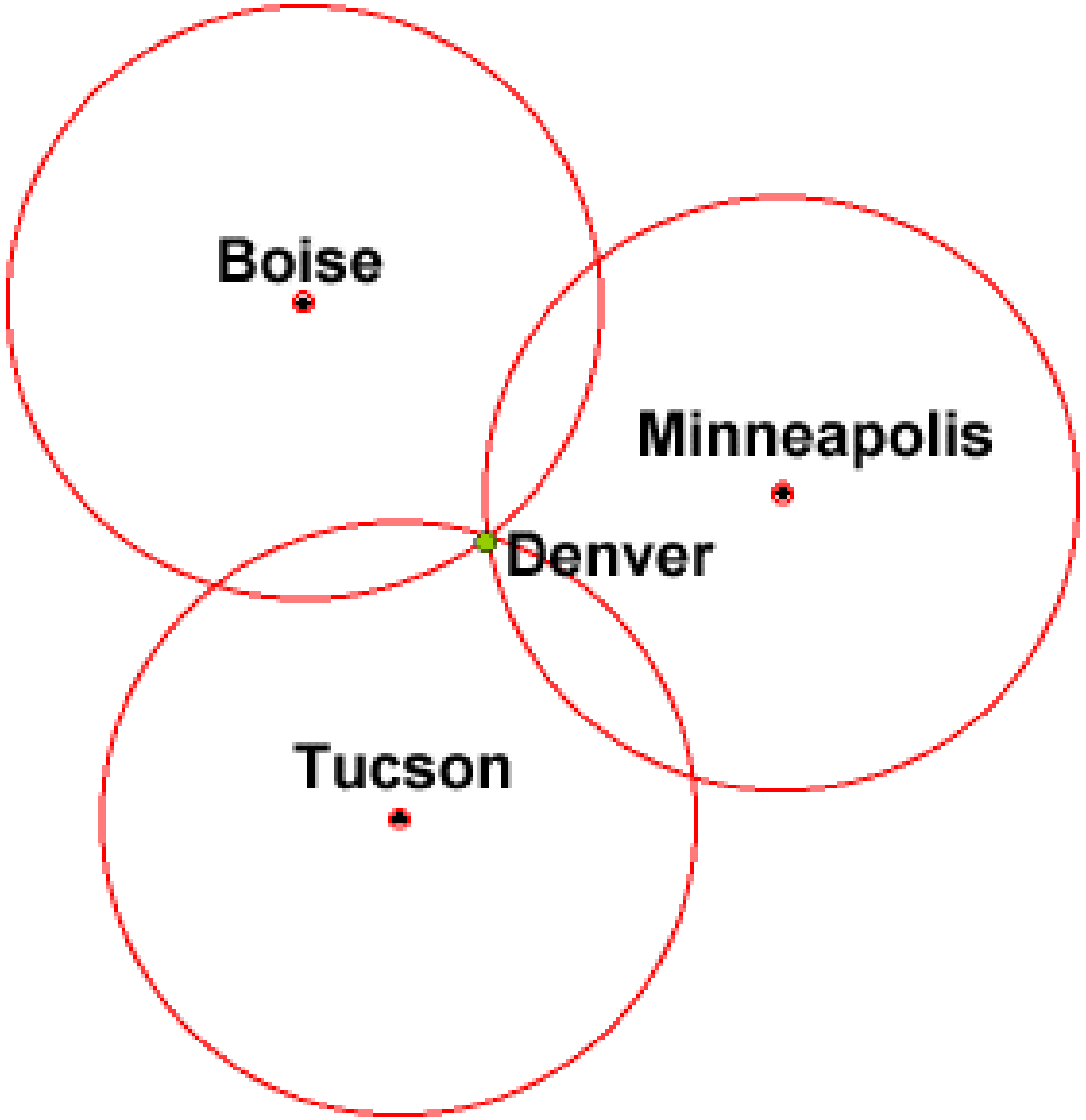
Trilateration 2D



Trilateration 2D

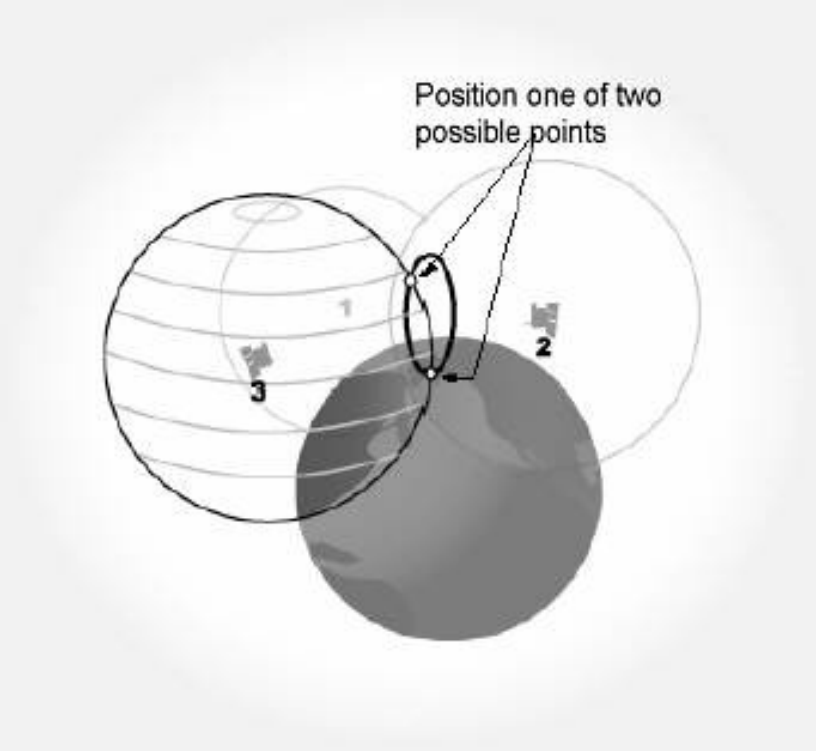


Trilateration 2D



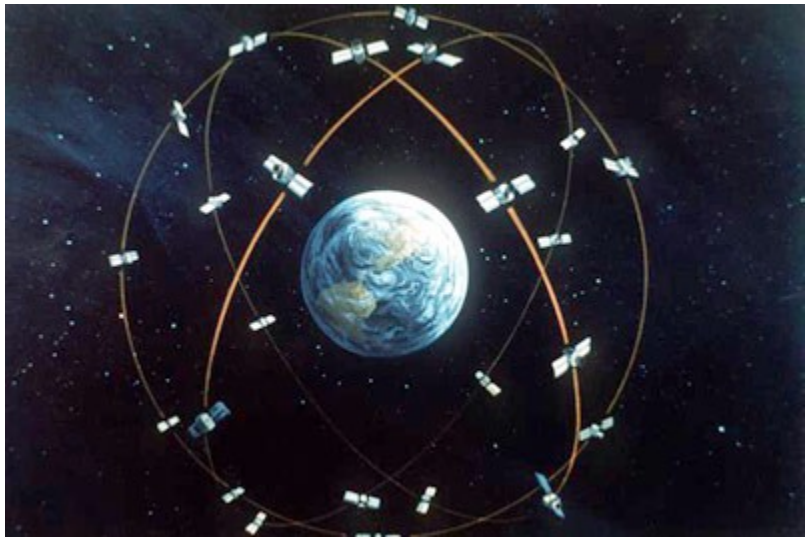
Trilateration 3D

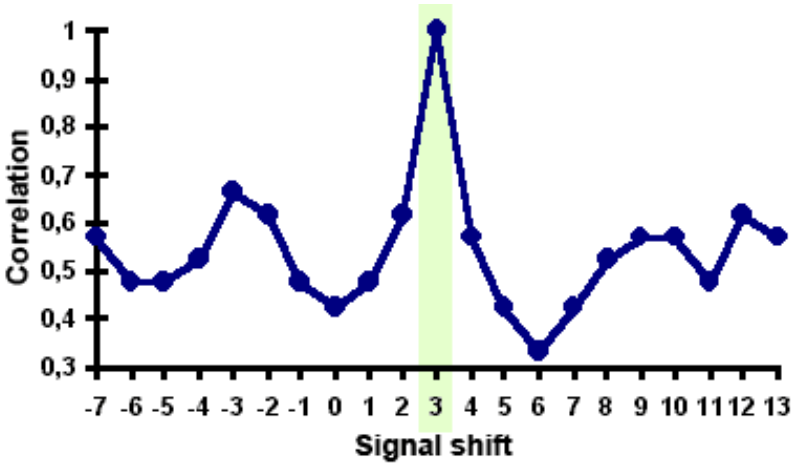
- How many sources do we need for 3D Trilateration?
- What is the bare Minimum we need for 3d Trilateration?
- Can we use the earth?



GPS (Global Positioning System)

- **Need to know:**
  - Position of Satellites
  - Distance to those satellites
- **Find Out:**
  - Satellite transmits code at time A
  - Receiver measures amount of time till it can match that signal
  - Multiply By C to get distance
- **Whats Wrong?**

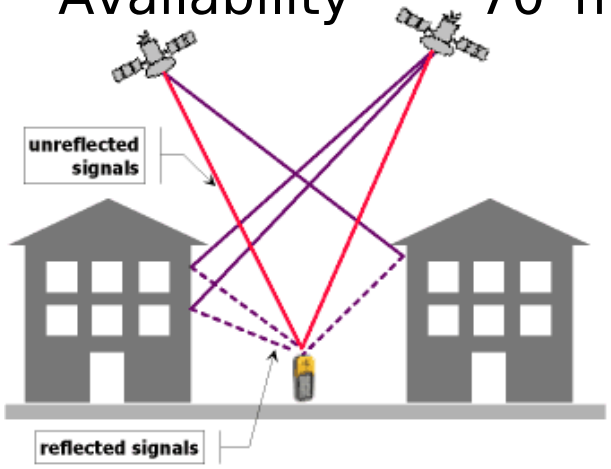




GPS (Global Positioning System)

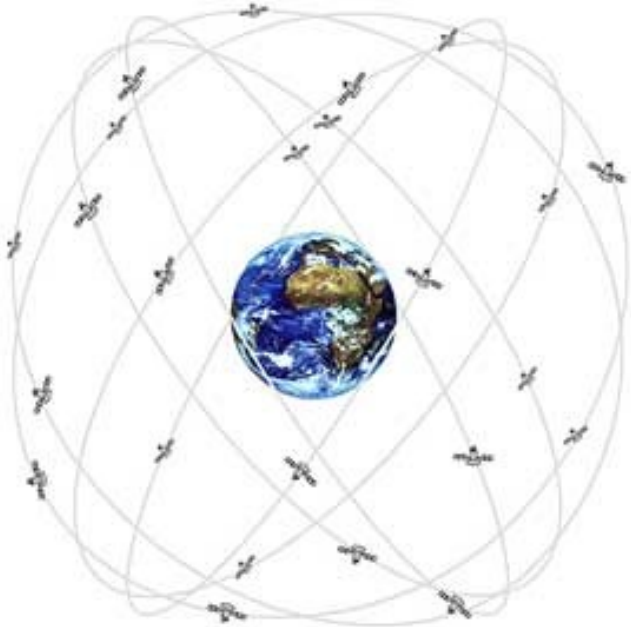
- **Problems:**
  - Receiver Does not Have Atomic Clock
  - Ionosphere and Troposphere Refract GPS Signals
  - Measurement Noise
  - Ephemeris Data
  - Clock Drift
  - Multi-Path
  - Selective Availability

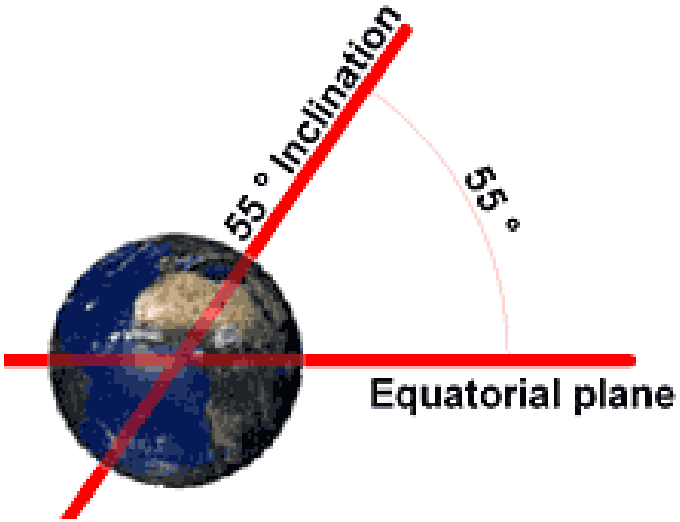
- **GPS Budget**
  - Ionosphere 5 meters
  - Troposphere .5 meters
  - Noise 1 meters
  - Ephemeris 2.5 meters
  - Clock Drift 1 meter
  - Multi Path 1 meters
  - Availability 70 meters



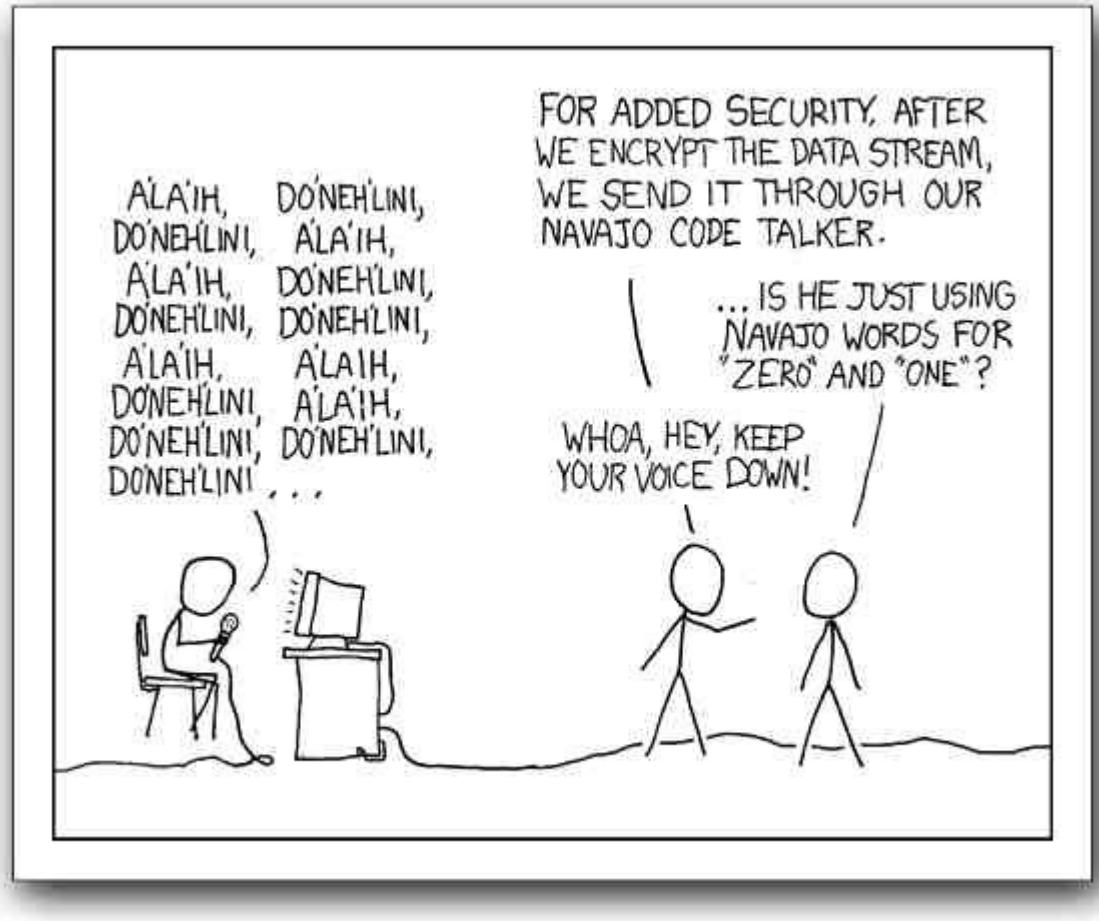
GPS

- **Satellites:**
  - Orbit Speed 3.9 km/s
  - Period of 11 h 58 s
  - Altitude of 20200 km
  - 6 planes
  - 60 degree inclination





DGPS (Differential GPS)



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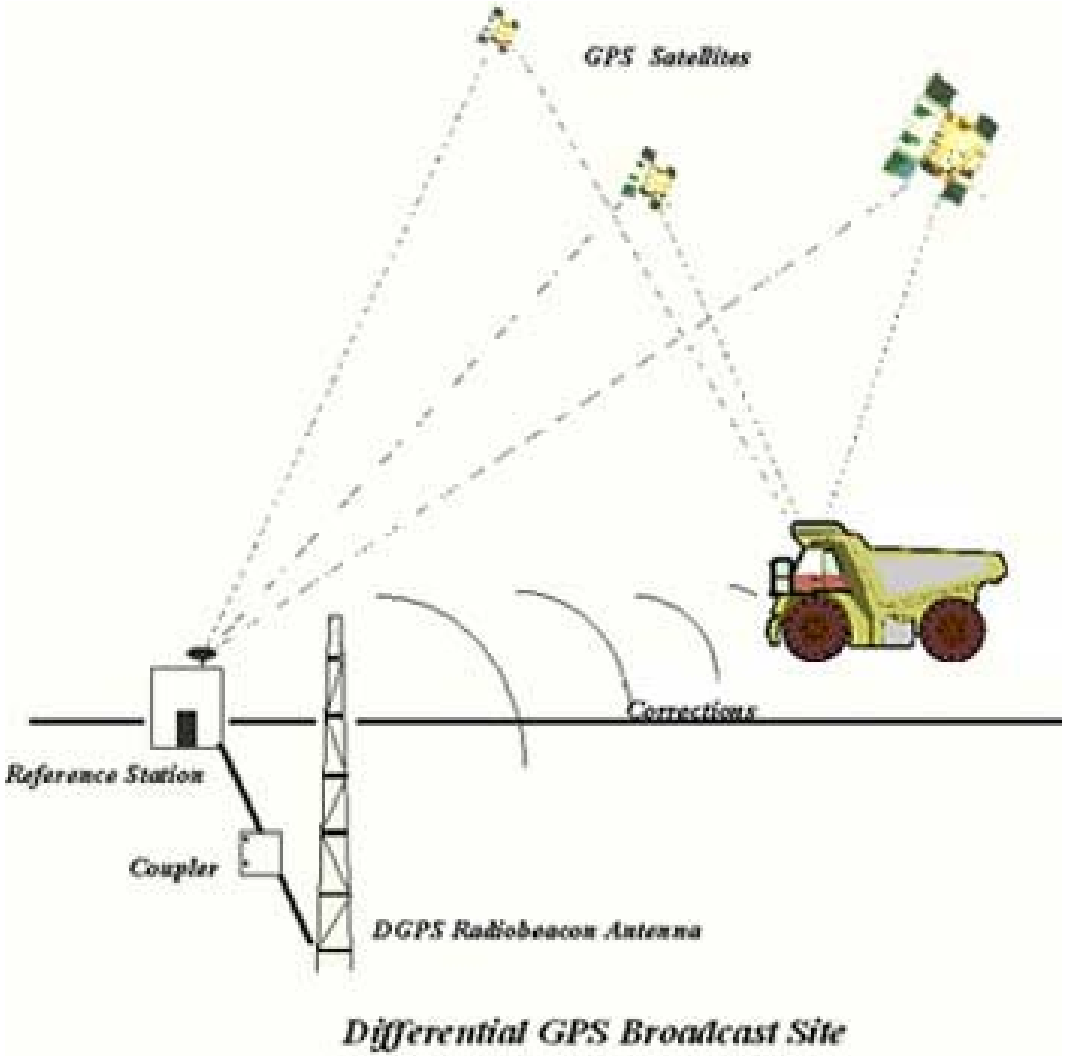
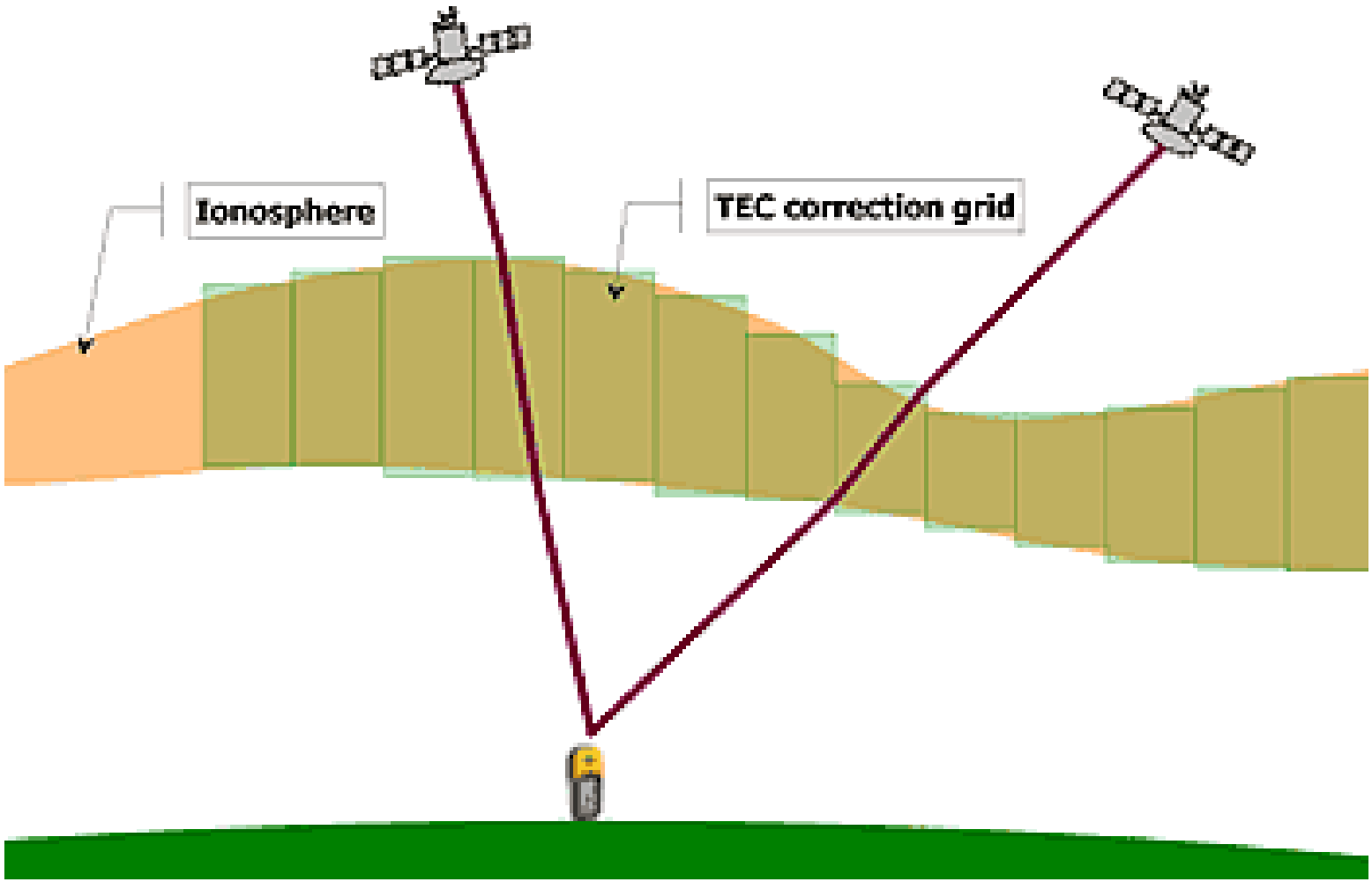


Differential GPS Broadcast Site

WAAS(Wide Area Augmentation System)

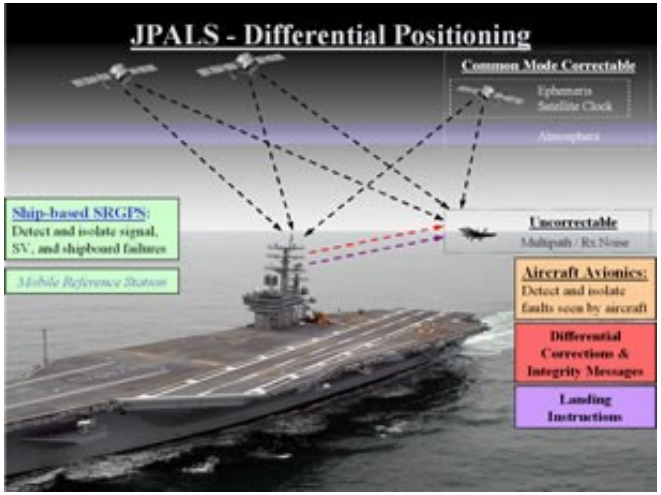


GPS: The Score

- **The Score**
  - 100 m GPS
  - 3-5 m DGPS
  - <3 m WAAS
  - Cm on systems that integrate for long periods of time
- **Whats on the Street:**
  - $56 Copernicus GPS chip on Sparkfun
  - 39 second Cold Start
  - 19X19X2.54 mm
  - DGPS and WAAS capable
  - 1Hz update rate
- **What to Watch for**
  - GPS > 12 channels == scam. 12 sats visible from any place on the earth
  - 1Hz receiver < $100 and dropping
  - Small antennae == accuracy problems
  - Sub meter gets expensive

GPS: Applications and The Future

- **MQ-X Series Drones (SAR)**
  - Predator, Reaper, Warrior
- **Local Area Augmentation System**
  - Support auto landings at airports
- **Joint Precision and Landing System**
  - System for Automatic Landing of Aircraft
- **BOSS**
  - Differential GPS system

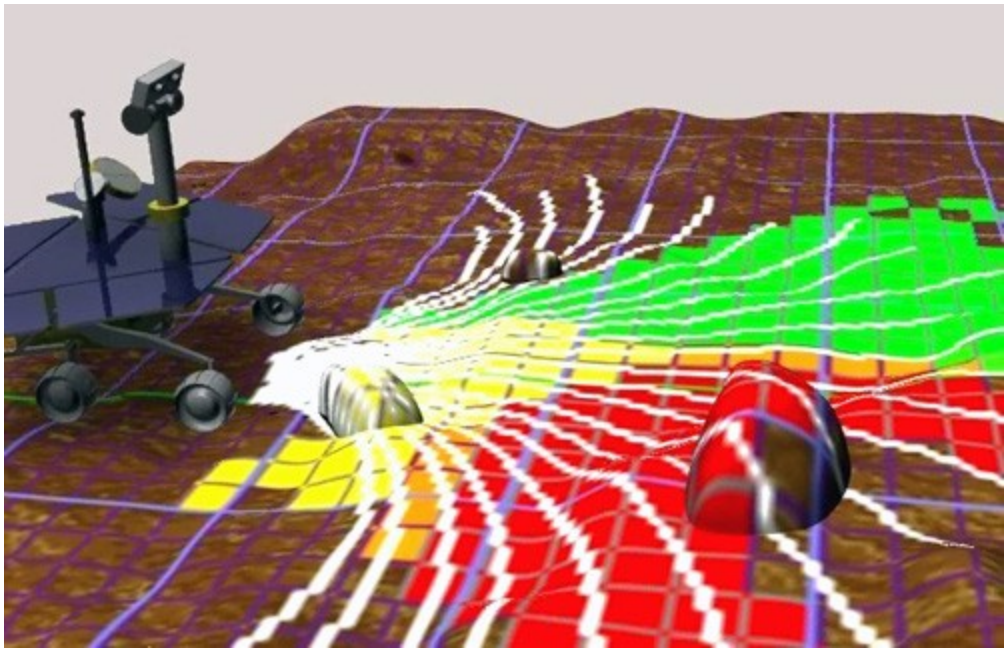


Exercise

- Think of one application that may be better served by sub meter accuracy of GPS that is not already served by 1-3 meter resolution. This carries with it the condition that sub meter resolution GPS often times involves more lengthy acquisition periods (between 5 to 10 minutes). Think of one application that may be better served by sub centimeter accuracy of GPS that is not already served by larger resolutions. Noting that sub centimeter resolution of GPS can require acquisition periods of up to 40 minutes. For each of these pick a suitable GPS device and explain why you chose it.

Landmark Navigation

- **Pioneered By Mars Rovers**
  - Stereographic Vision
  - Global Mapping
  - Path Planning
  - Multi-Resolution
  - VxWorks



Citations

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