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GLOBAL POSITIONING SYSTEMS

Outline

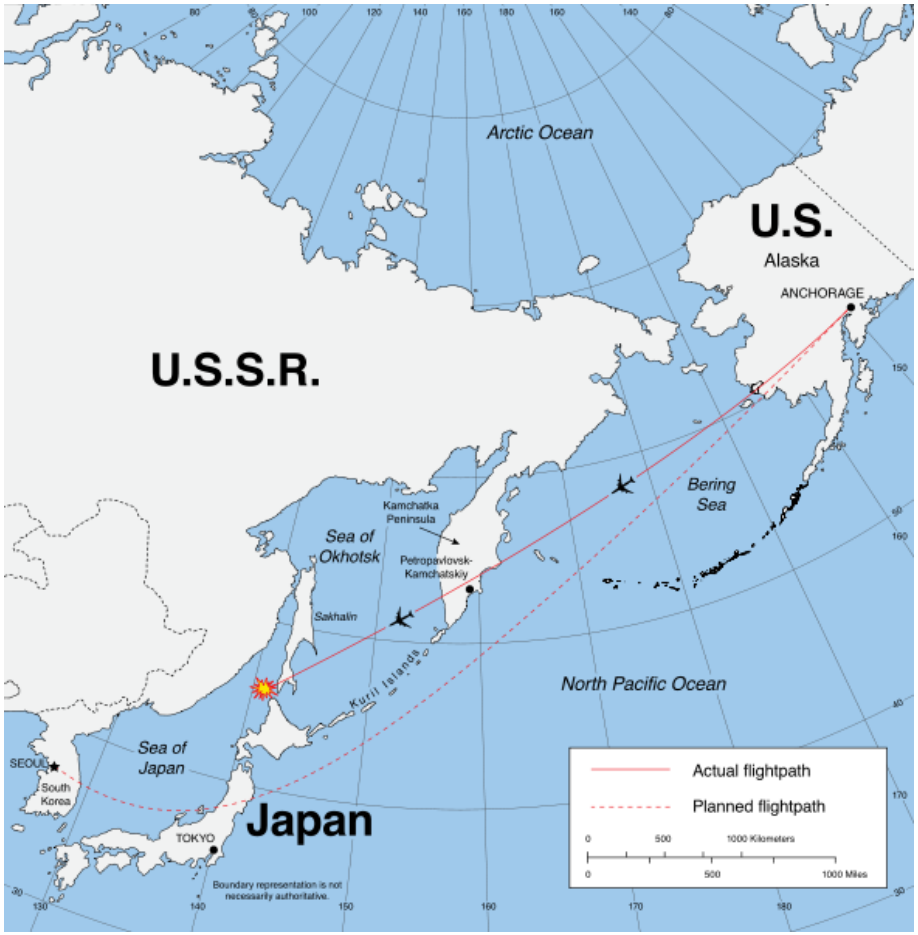
- History
  - Selective Availability
- Space Segment
  - Relativistic Effects
    - Special Relativity
    - General Relativity
- Control Segment
- User Segment
  - Trilateration
  - Corrections
- Errors
- Conclusion

History

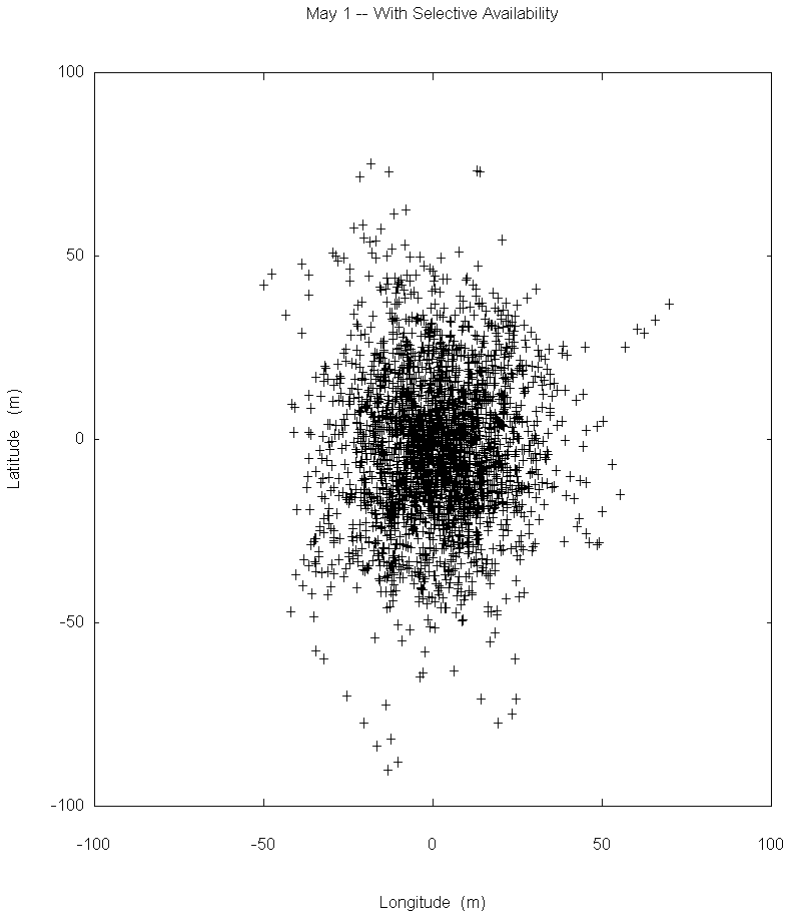
- 1957 USSR Sputnik 1
- Early 1960s US Navy, Army, and Air Force formulated their own ideas for GPS.
  - 1973 first satellite NAVSTAR
  - 11 more launched between 1978-1985
  - 24 satellites with 4 spare were in orbit by 1993
  - Initially intended for military use only
    - Navigation for nuclear weapons

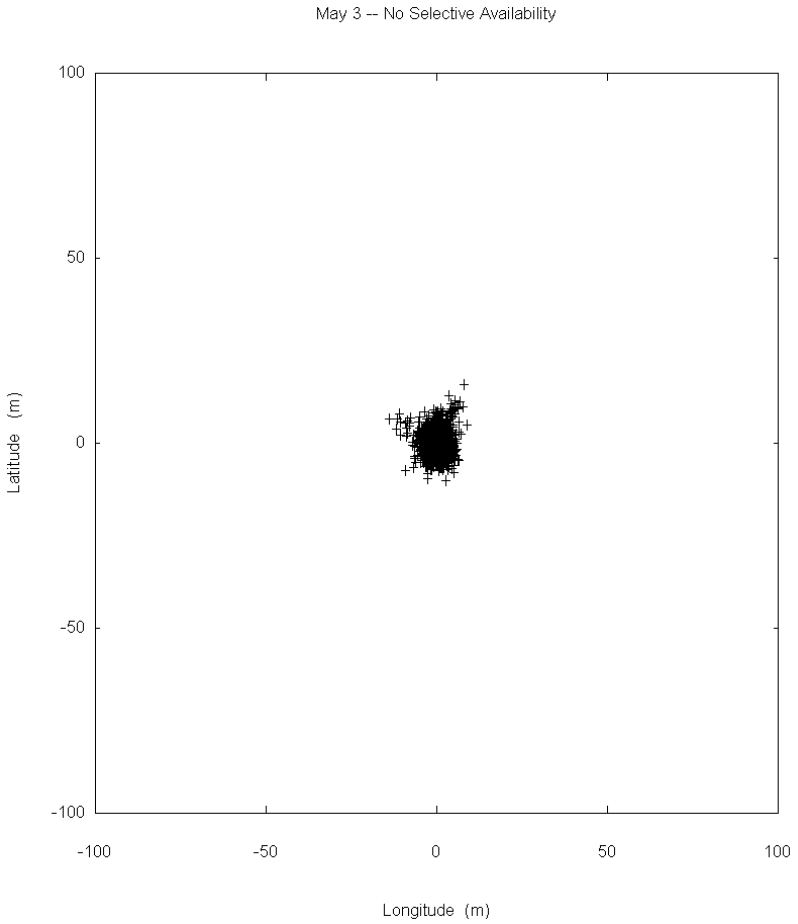
History (cont.)

- 1983 Korean Airlines flight went off track into Soviet airspace and was shot down.
- President Reagan: GPS for civilian use
- Current restrictions
  - Export license required for receivers operating above 515 m/s and 15 km altitude
  - Prevents ballistic missile
- Selective Availability 2000
  - Encrypted frequencies



Selective Availability





Space Segment

- Constellation of 24 GPS satellites
  - 4 – 12 visible
- 4 Earth radii
- Orbital period of 12 hours
- Atomic clocks
  - $50K – $100K
- Accuracy
  - GPS: 5 – 10 meters
  - DGPS: 1 meter

Relativistic Effects

Special Relativity

- Time dilation
  - Clocks tick slower when they're in motion
  - 7,200 ns/day

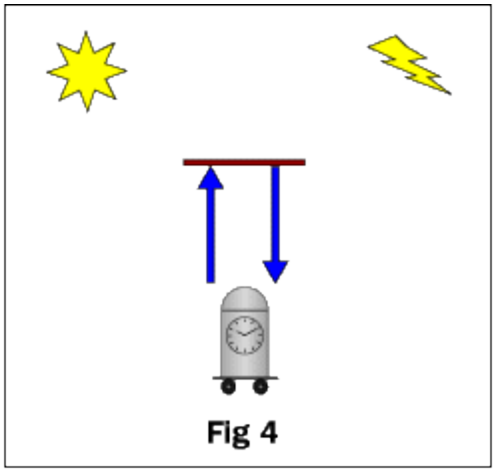


Fig 4

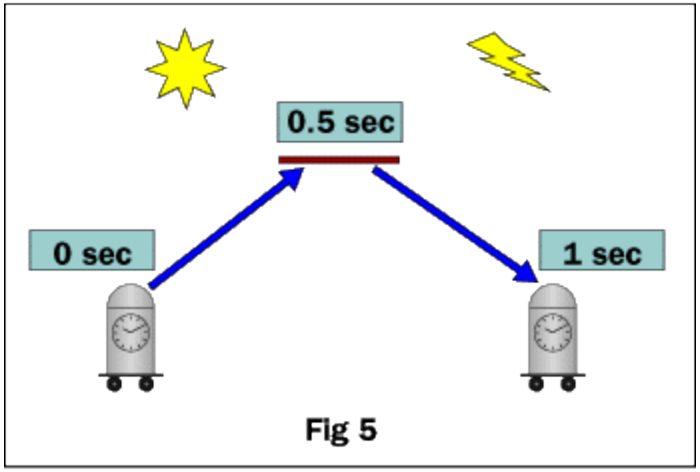
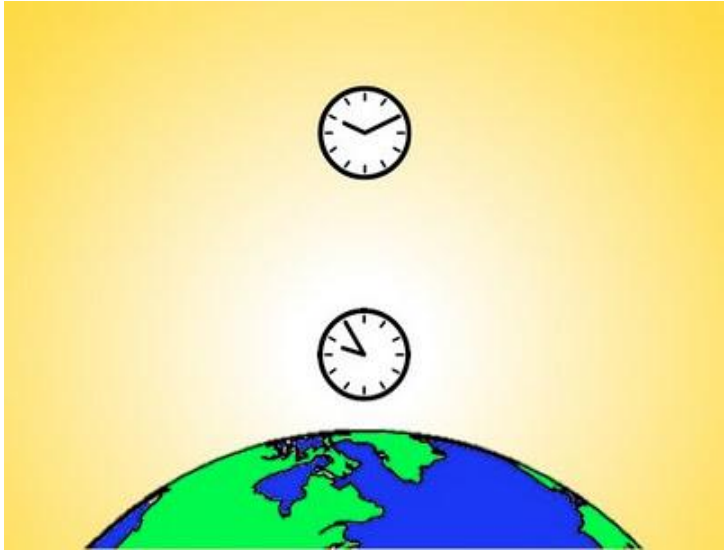


Fig 5

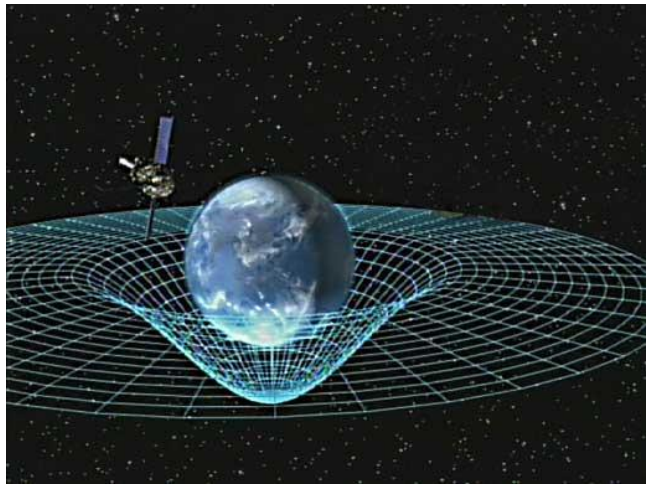
Relativistic Effects (cont.)

General Relativity

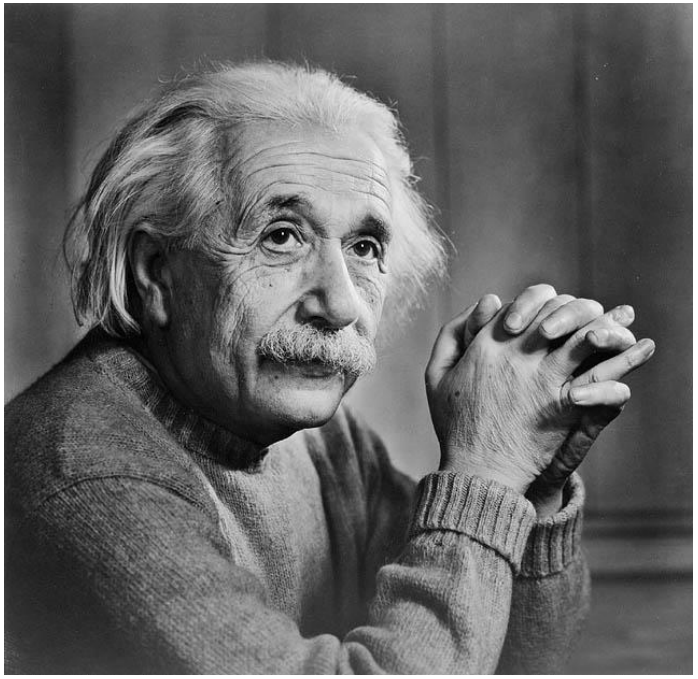
- Gravitational time dilation
  - Clocks on Earth's surface will tick slower than a clock in orbit around Earth.



- Spacetime is curved by massive objects
- 45,900 ns/day



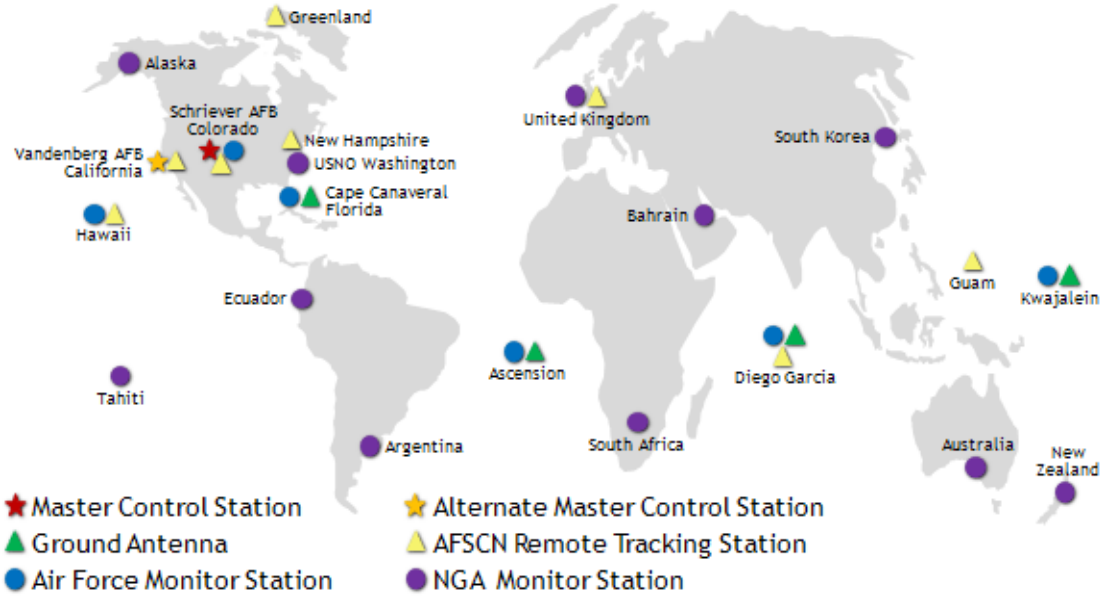
Relativistic Effects (cont.)



- Special relativity
  - Clocks tick slower
- General relativity
  - Clocks tick faster
- Rates are set in clocks before satellites are launched.

Control Segment

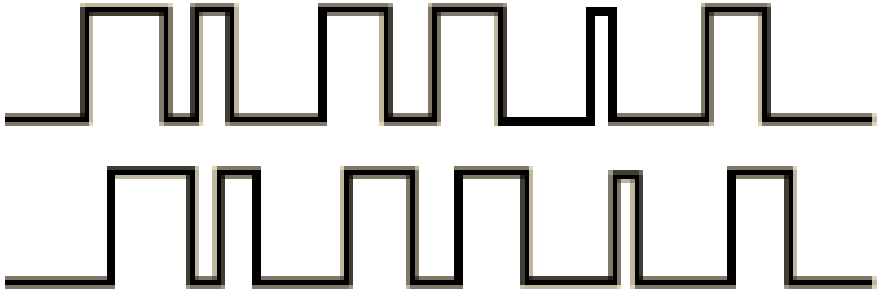
- Master Control Station, Monitor Stations, and Ground Antennas
- Corrects for changes in a satellites' orbit and timing.
- This information is sent back to the satellite so it can send its accurate position to GPS receivers.



User Segment

Calculating the distance to GPS satellites

- Satellites broadcast pseudo random code
  - Digital on-off pulses
  - Unique
  - No interference

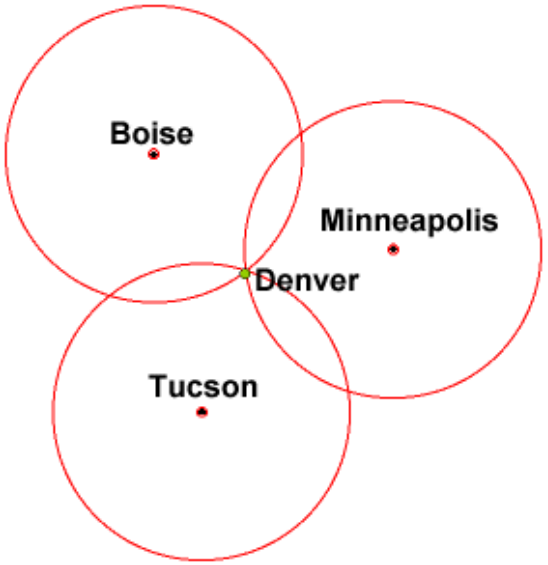


Pseudo Random Code

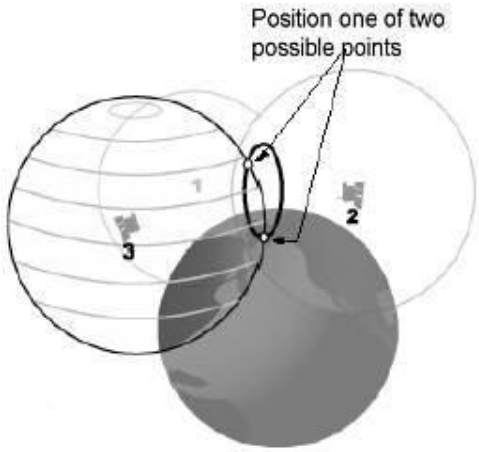
- d = ct

Trilateration

- Process of determining position using geometry of circles, spheres, or triangles.



2D Trilateration



3D Trilateration

Corrections

- GPS receivers have quartz clocks
  - Inaccurate
- Spheres may not intersect
  - Receiver will find a time correction to make the spheres intersect at one point
- Receiver's clock is set to universal time
- Cross-checked with a 4^{th} satellite

Errors

- Differential GPS
  - Radio waves deflected in atmosphere
- Multi-path errors
  - Buildings, cars
- Atomic clock
  - Control segment corrects

Conclusion

- PRC is used to determine the distance to satellites.
- Trilateration used to obtain position.
- Control segment corrects for errors.
- Relativity is required in order to obtain an accurate position.
- Experimental evidence for relativity.
- Free service, can be used in any weather conditions.

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