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Geographic Information system

INTRODUCTION TO GPS

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http://pirun.ku.ac.th/~fengwks/gis/lecture/6GPSLecture.pdf

Presentation Outline

I. Learning Format

II. GPS Basics

III. GPS "Under the Hood"

IV. Datums and Coordinate Systems

V. Mobile Mapping Technology

VI. Hands on with GPS

Learning Format

- Lecture
  - One hour presentation and in class orientation to GeoXT
- Lab
  - Field trip (when?) to practice using the GPS in the field

What is GPS?

The Global Positioning System (GPS)

A Constellation of Earth-Orbiting Satellites Maintained by the United States Government for the Purpose of Defining Geographic Positions On and Above the Surface of the Earth. It consists of Three Segments:

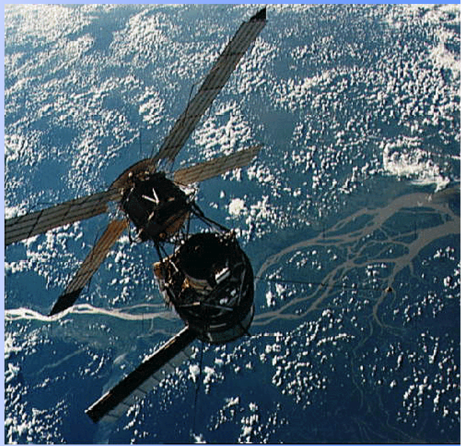
User Segment

Control Segment

Space Segment

GPS Satellites (Satellite Vehicles(SVs))

- First GPS satellite launched in 1978
- Full constellation achieved in 1994
- Satellites built to last about 10 years
- Approximately 2,000 pounds,17 feet across
- Transmitter power is only 50 watts or less



GPS Lineage

- Phase 1: 1973-1979
  CONCEPT VALIDATION
  1978- First Launch of Block 1 SV
- Phase 2: 1979-1985
  FULL DEVELOPMENT AND TESTS
- Phase 3: 1985-Present
  PRODUCTION AND DEPLOYMENT

Navigation Satellite Systems in the World

- NAVSTAR (Navigation Satellite Timing and Ranging)
  - By United States Air Force, USA
- GLONASS (Global Navigation Satellite System)
  - By Aerospace Defence Forces Russians
- Galileo
  - By European Union (EU) and European Space Agency (ESA)

Precise Positioning System (PPS)

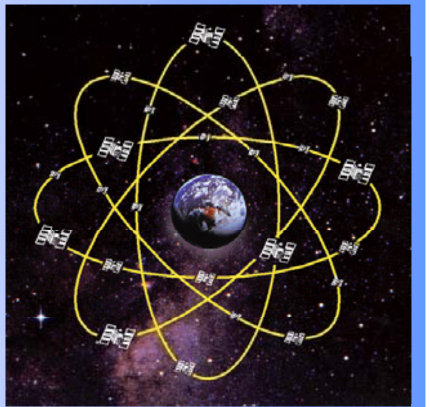
- Authorized users ONLY
- U. S. and Allied military
- Requires cryptographic equipment, specially equipped receivers
- Accurate to 21 meters 95% of time

Standard Positioning Service (SPS)

- Available to all users
- Accuracy degraded by Selective Availability until 2 May 2000
  - Horizontal Accuracy: 100m
- Now has roughly same accuracy as PPS

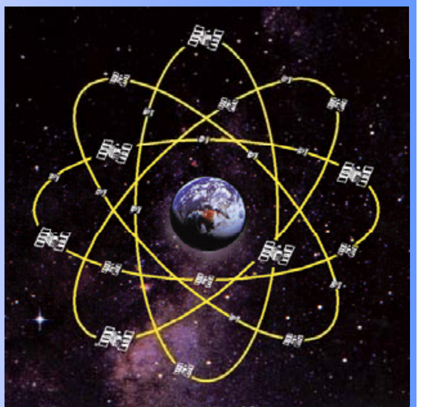
Space Segment

- 24+ satellites
  - 6 planes with 55° inclination
  - Each plane has 4-5 satellites
  - Broadcasting position and time info on 2 frequencies
  - Constellation has spares

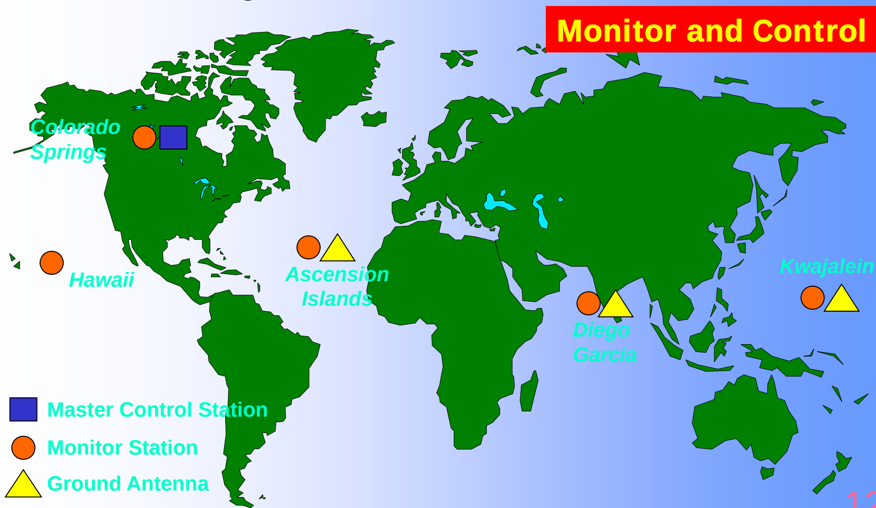


Space Segment

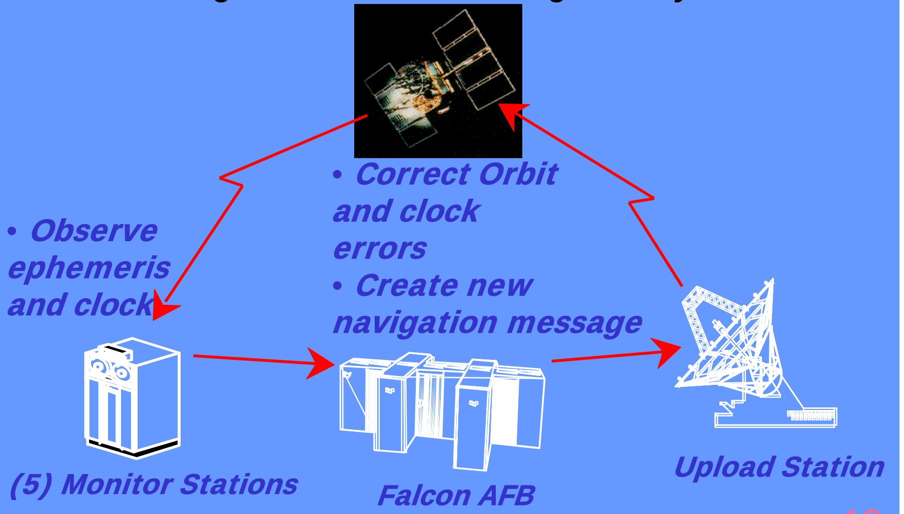
- Very high orbit
  - 20,200 km
  - **1 revolution in approximately 12 hrs**
  - **Travel approx. 7,000mph**
- Considerations
  - Accuracy
  - Survivability
  - Coverage



Control Segment



Control Segment: Maintaining the System



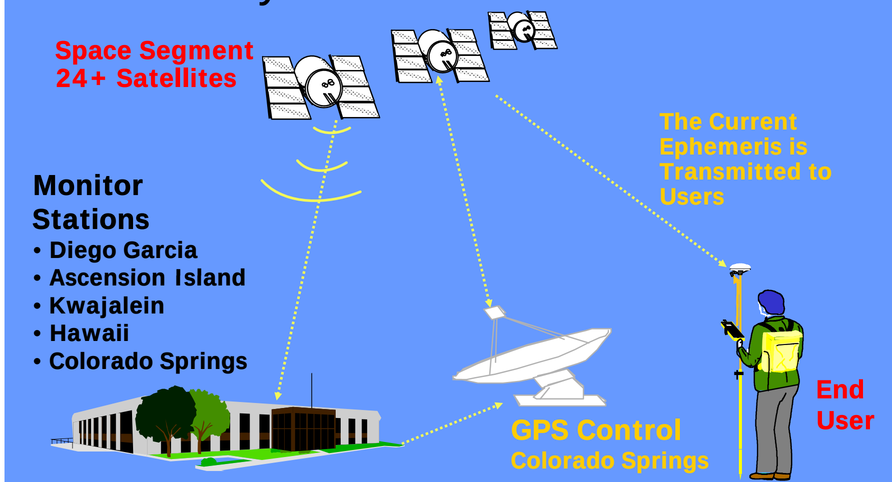
User Segment

- Over $19 Billion invested by DoD
- Dual Use System Since 1985
  (civil & military)
- Civilian community was quick to take advantage of the system
  - Hundreds of receivers on the market
  - 3 billion in sales, double in 2 years
  - 95% of current users
- DoD/DoT Executive Board sets GPS policy

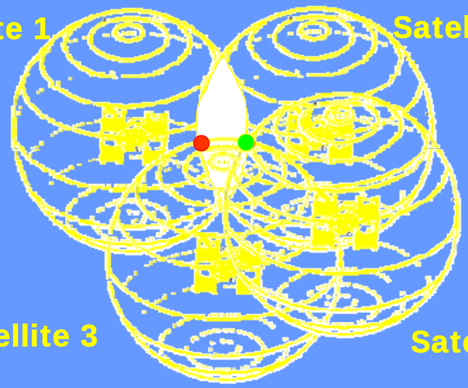
Common Uses for GPS

- Land, Sea and Air Navigation and Tracking
- Surveying/ Mapping
- Military Applications
- Recreational Uses

How the system works



Triangulation



Distance Measuring

The whole system revolves around time!!!

Distance = Rate x Time

second (Speed of Light)

Time = time it takes signal to travel from the SV to GPS receiver

Each satellite carries around four atomic clocks

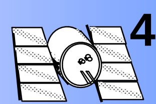
Uses the oscillation of cesium and rubidium atoms to measure time

Accuracy?

plus/minus a second over more than 30,000 years!!

SV and Receiver Clocks

- **SV Clocks**
  - **2 Cesium & 2 Rubidium in each SV**
  - **$100,000-$500,000 each**
- **Receiver Clocks**
  - **Clocks similar to quartz watch**
  - **Always an error between satellite and receiver clocks (Δ t)**
- **4 satellites required to solve for x, y, z, and Δ t**



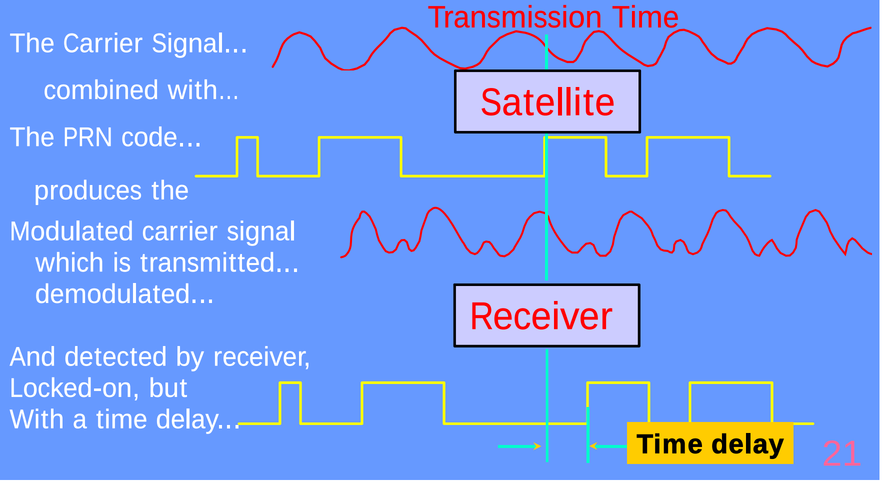
- PROBLEM
  - Can't use atomic clocks in receiver

Cesium Clock = $$$$$$$!!!

Size of PC

- SOLUTION
  - Receiver clocks accurate over short periods of time
  - Reset often
  - 4th SV used to recalibrate receiver clock

Breaking the Code



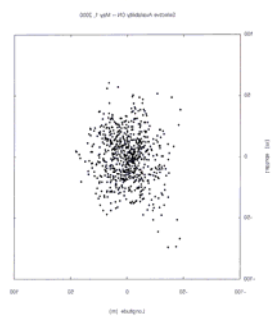
Accuracy and Precision in GPS

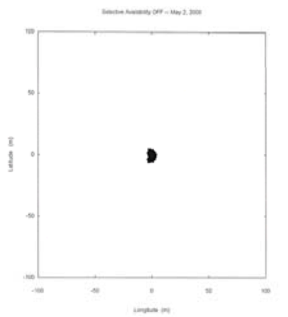
- Accuracy
  - The nearness of a measurement to the standard or true value
- Precision
  - The degree to which several measurements provide answers very close to each other.

What affects accuracy and precision in GPS?

Sources of Error

- Selective Availability
  - Intentional degradation of GPS accuracy
  - 100m in horizontal and 160m in vertical
  - Accounted for most error in standard GPS
  - Turned off May 2, 2000

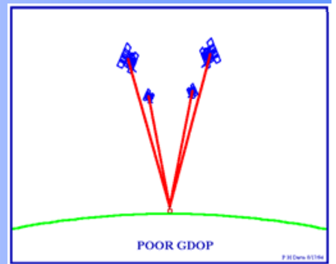


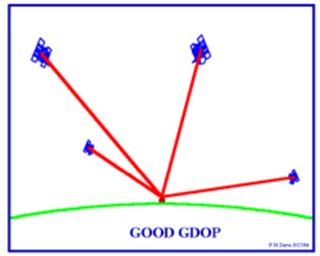


Sources of Error

- Geometric Dilution of Precision (GDOP)
  - Describes sensitivity of receiver to changes in the geometric positioning of the SVs
- The higher the DOP value, the poorer the measurement

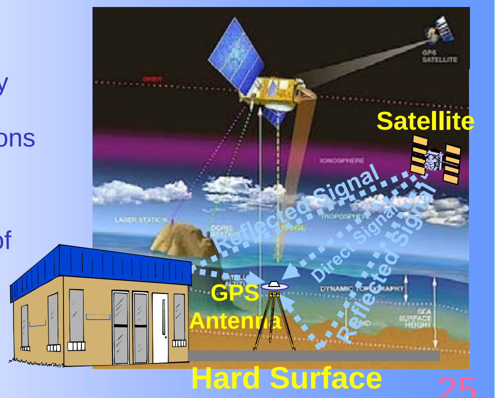
QUALITY	DOP
Very Good	*1-3*
Good	*4-5*
Fair	*6*
Suspect	*>6*



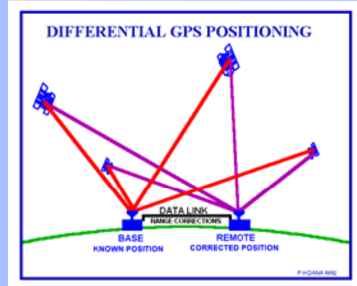


Sources of Error

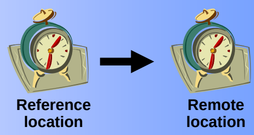
- Clock Error
  - Differences between satellite clock and receiver clock
- Ionosphere Delays
  - Delay of GPS signals as they pass through the layer of charged ions and free electrons known as the ionosphere.
- Multipath Error
  - Caused by local reflections of the GPS signal that mix with the desired signal



Differential GPS



- Method of removing errors that affect GPS measurements
- A base station receiver is set up on a location where the coordinates are known
- Signal time at reference location is compared to time at remote location
- Time difference represents error in satellite's signal
- Real-time corrections transmitted to remote receiver
  - Single frequency (1-5 m)
  - Dual frequency (sub-meter)



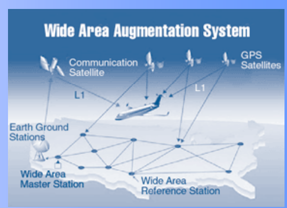
= Error

- Post-Processing DGPS involves correcting at a later time

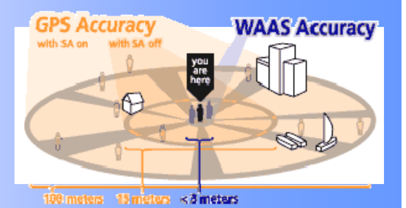
www.ngs.noaa.gov/OPUS

Online post-processing

Wide Area Augmentation System (WAAS)



- System of satellites and ground stations that provide GPS signal corrections
- 25 ground reference stations across US
- Master stations create GPS correction message
- Corrected differential message broadcast through geostationary satellites to receiver
- 5 Times the accuracy (3m) 95% of time



Why should I worry about datums and coordinate systems when using GPS?

Datums and Coordinate Systems

- Many datums and coordinate systems in use today
- Incorrect referencing of coordinates to the wrong datum can result in position errors of hundreds of meters
- With, sub-meter accuracy available with today's GPS, careful datum selection and conversion is critical!

Selected Reference Ellipsoids

Ellipse	Semi-Major Axis (meters)	1/Flattening
Airy 1830	6377563.396	299.3249646
Bessel 1841	6377397.155	299.1528128
Clarke 1866	6378206.4	294.9786982
Clarke 1880	6378249.145	293.465
Everest 1830	6377276.345	300.8017
Fischer 1960 (Mercury)	6378166.0	298.3
Fischer 1968	6378150.0	298.3
G R S 1967	6378160.0	298.247167427
G R S 1975	6378140.0	298.257
G R S 1980	6378137.0	298.257222101
Hough 1956	6378270.0	297.0
International	6378388.0	297.0

The Austin Capitol Dome Liberty Star Horizontal Control Station
(The star in the hand of the Goddess of Liberty)

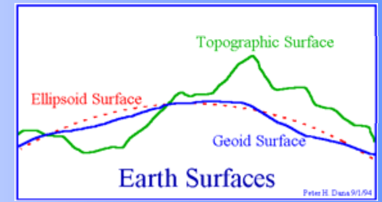
Datum	Coordinate System	Coordinates	Units
NAD-83	Geodetic Latitude, Longitude	[illegible]	deg:min:sec
NAD-27	Geodetic Latitude, Longitude	[illegible]	deg:min:sec
WGS-72	Geodetic Latitude, Longitude	[illegible]	deg:min:sec
NAD-83	UTM Easting, Northing, Zone	[illegible]	meters
NAD-27	UTM Easting, Northing, Zone	621193.18, 3349688.21	meters
NAD-83	Military Grid Reference System	[illegible]	meters
NAD-27	Military Grid Reference System	[illegible]	meters
NAD-83	State Plane, TX C 4203 Easting, Northing	[illegible]	meters
NAD-27	State Plane, TX C 4203 Easting, Northing	[illegible]	feet
NAD-83	State Plane, TX SC 4204 Easting, Northing	721201.977, 4271229.432	meters
NAD-27	State Plane, TX SC 4204 Easting, Northing	[illegible]	feet
WGS-72	World Geographic Reference System	[illegible]	deg. and min.
	VOR-DME Bearing, Distance, VOR ID	230.46, 2.271, 114.6 Ch.93 AUS	deg,nmi,id
	Loran C GRI 7980 W, X, Y, Z TDs	[illegible]	microsec.
	U.S. Postal Zip Code (5-digits)	78705	

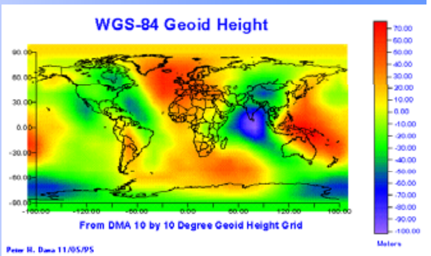
One Location Described by Different Coordinate Systems

P. H. Dana 8/20/98

Geodetic Datums: What are they?

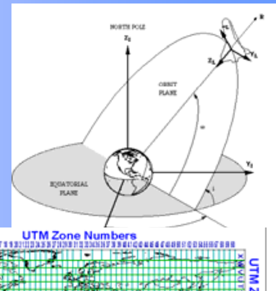
- Define the size and shape of the earth
- Used as basis for coordinate systems
- Variety of models:
  - Flat earth
  - Spherical
  - Ellipsoidal
- WGS 84 defines geoid heights for the entire earth

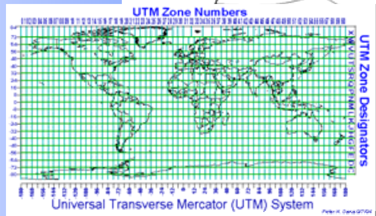




Coordinate Systems: What are they?

- Based on Geodetic Datums
- Describe locations in two or three dimensions (ie. X,Y,Z or X,Y)
- Local and Global
- Common systems
  - Geodetic Lat, Long (global)
  - UTM (local)
  - State Plane (local)
- Variety of transformation methods

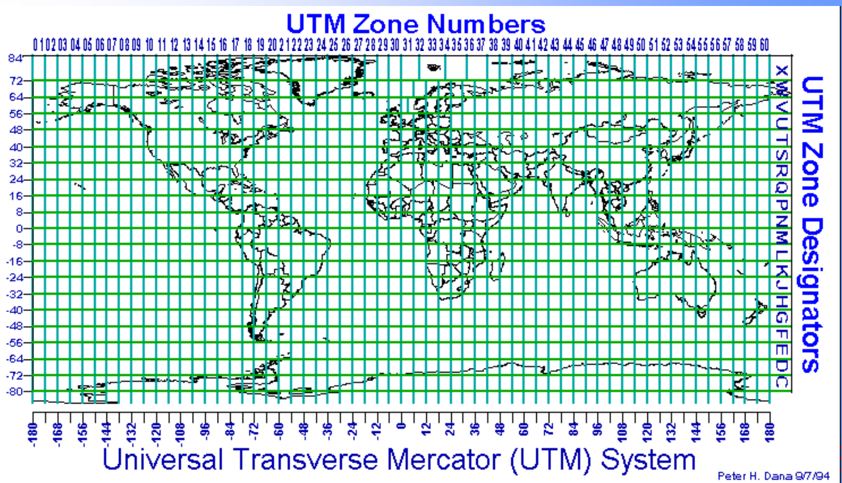




www.uwgb.edu/dutchs/UsefulData/UTMFormulas.HTM

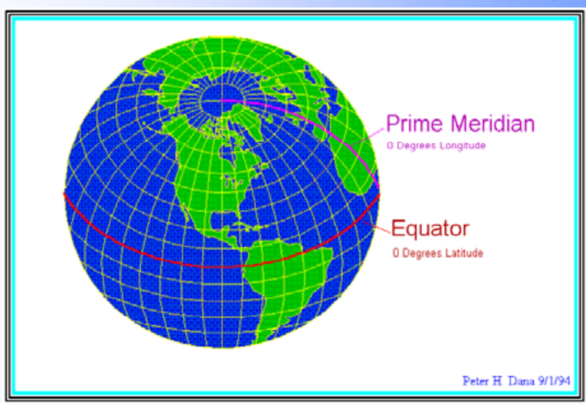
Online conversion tool

World UTM Zones



Geodetic Latitude, Longitude

- Prime Meridian and Equator are reference planes used to define latitude and longitude



Which is the correct location?

Same location can have many reference positions, depending on coordinate system used

The Austin Capitol Dome Liberty Star Horizontal Control Station
(The star in the hand of the Goddess of Liberty)

Datum	Coordinate System	Coordinates	Units
NAD 83	Geodetic Latitude, Longitude	30:16:28.82 N, 97:44:25.19 W	deg:min:sec
NAD-27	Geodetic Latitude, Longitude	30:16:28.03 N, 97:44:24.09 W	deg:min:sec
WGS-72	Geodetic Latitude, Longitude	30:16:28.68 N, 97:44:25.75 W	deg:min:sec
NAD-83	UTM Easting, Northing, Zone	621160.98, 3349893.53 14 R	meters
NAD-27	UTM Easting, Northing, Zone	621193.18, 3349688.21	meters
NAD-83	Military Grid Reference System	14RPU2116149894	meters
NAD-27	Military Grid Reference System	14RPJ2119349688	meters
NAD-83	State Plane, TX C 4203 Easting, Northing	949465.059, 3070309.475	meters
NAD-27	State Plane, TX C 4203 Easting, Northing	2818560.55, 230591.76	feet
NAD-83	State Plane, TX SC 4204 Easting, Northing	721201.977, 4271229.432	meters
NAD-27	State Plane, TX SC 4204 Easting, Northing	2397741.25, 889749.98	feet
WGS-72	World Geographic Reference System	FJHA1516	deg. and min.
	VOR-DME Bearing, Distance, VOR ID	230.46, 2.271, 114.6 Ch.93 AUS	deg,nmi,id
	Loran-C GRI 7980 W, X, Y, Z TDs	10998.9,24795.0,47040.8,63902.3	microsec.
	U.S. Postal Zip Code (5-digits)	78705	

One Location Described by Different Coordinate Systems

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"Mobile Mapping"

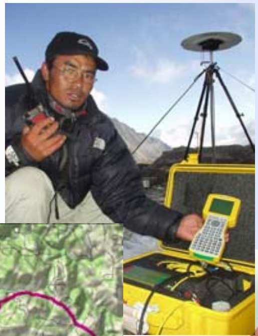
- Integrates GPS technology and GIS software
- Makes GIS data directly accessible in the field
- Can be augmented with wireless technology

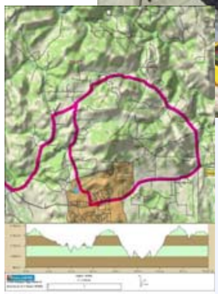


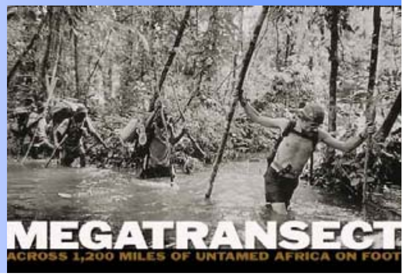
Mobile Mapping Pros and Cons

- Pros
  - More efficient data entry
  - Ready access to GIS data
  - Less transcription error
  - Possible real-time upload/download through wireless
- Cons
  - Cost
  - Data storage limit
  - Digital data can be lost/corrupted

Hands on with GPS





OBJECTID	Northing	Easting	GPSDate	GPSDateTime
1	3982854.745	656956.881	09-Apr-04	09-Apr-04
2	3982854.748	656956.885	09-Apr-04	09-Apr-04
3	3982854.84	656956.953	09-Apr-04	09-Apr-04
4	3982854.697	656957.42	09-Apr-04	09-Apr-04
5	3982854.55	656957.393	09-Apr-04	09-Apr-04
6	3982854.539	656957.365	09-Apr-04	09-Apr-04
7	3982854.443	656957.304	09-Apr-04	09-Apr-04
8	3982854.37	656957.461	09-Apr-04	09-Apr-04
9	3982854.303	656957.619	09-Apr-04	09-Apr-04
10	3982854.089	656957.571	09-Apr-04	09-Apr-04
11	3982854.062	656957.672	09-Apr-04	09-Apr-04
12	3982854.02	656957.581	09-Apr-04	09-Apr-04
13	3982853.882	656957.36	09-Apr-04	09-Apr-04
14	3982853.776	656957.314	09-Apr-04	09-Apr-04
15	3982853.821	656957.262	09-Apr-04	09-Apr-04
16	3982853.9	656957.222	09-Apr-04	09-Apr-04
17	3982853.865	656956.896	09-Apr-04	09-Apr-04
18	3982853.825	656956.811	09-Apr-04	09-Apr-04
19	3982854.382	656954.229	09-Apr-04	09-Apr-04
20	3982857.014	656958.041	09-Apr-04	09-Apr-04

Question?

Thank you for your attention