Getting the Map into the Computer: GIS Data Development

- 4.1 Analog-to-Digital Maps
- 4.2 Finding Existing Map Data
- 4.3 Digitizing and Scanning
- 4.4 Field and Image Data
- 4.5 Data Entry
- 4.6 Editing and Validation

GIS maps are digital not analog

- Maps have a **communications function** but...
- A map has a **storage function** for spatial data
- Somehow, the visually “stored” data must **get digital**
- **Real and Virtual** maps

GIS Data Conversion

- Traditionally **most of the cost** of a GIS project
- This is a **one-time cost**
- Depends on **reuse**
- Requires **maintenance**

GIS Data Development Approaches

- Research for **existing** data
- If analog maps exist, **convert analog maps to virtual maps** (GIS data)
- If no analog maps, **aerial photography, remote sensing, GPS and ground survey** usually are obtained.

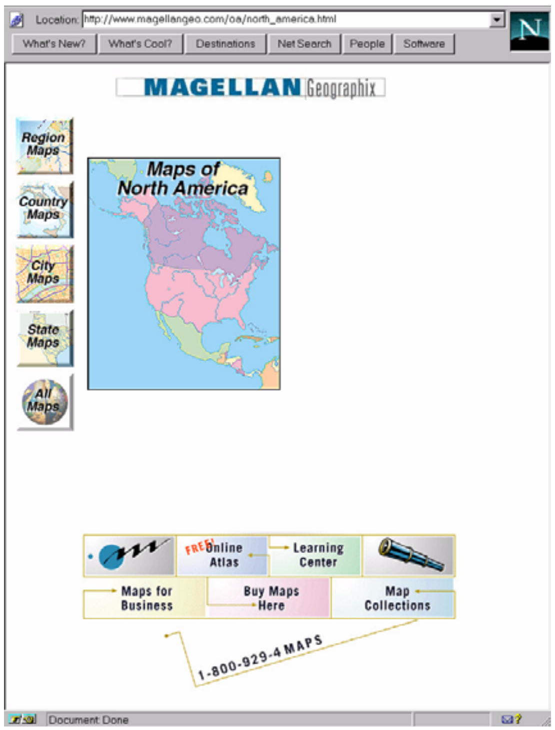
Finding Existing Map Data

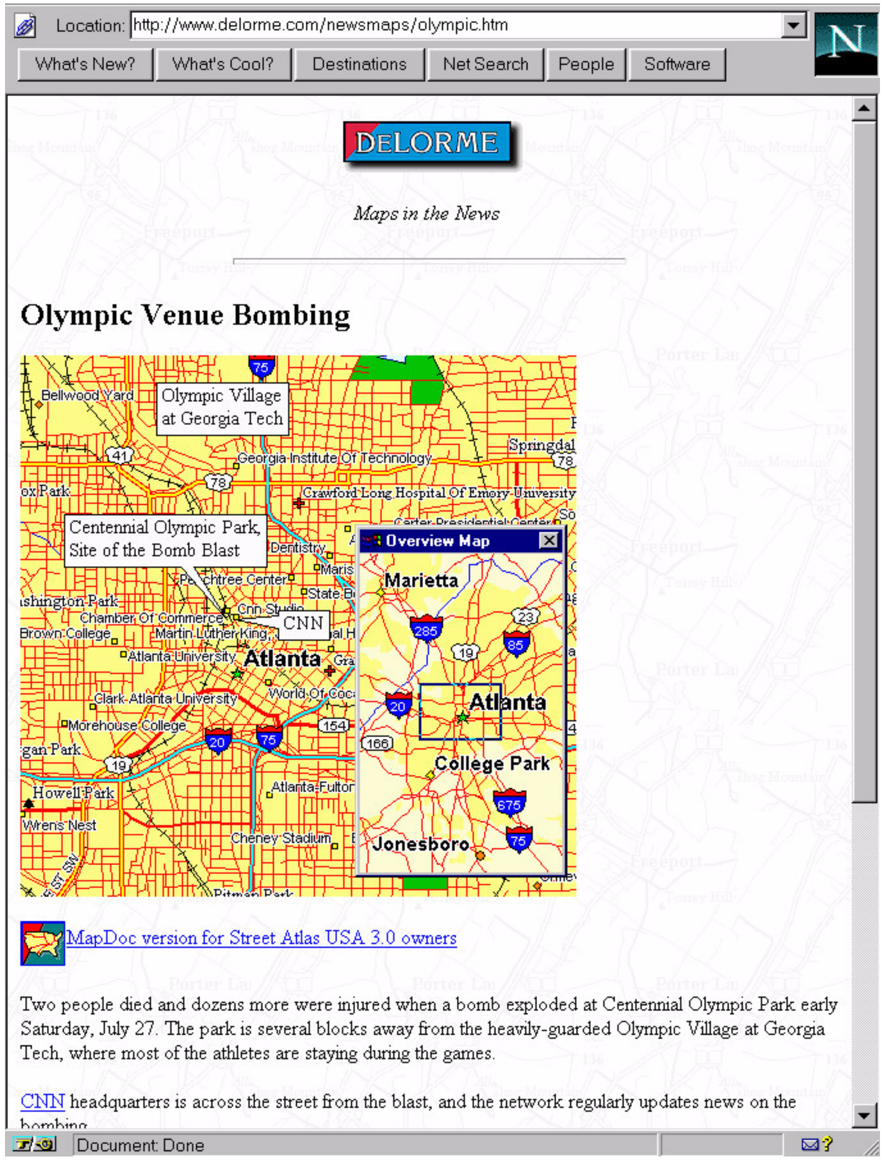
- Map libraries
- Reference books
- State and local agencies
- Federal agencies
- Commercial data suppliers e.g. GDT, Thompson, ETAK

Existing Map Data

- Existing map data can be found through a **map library**, via network searches, or on media such as CD-ROM and disk.
- Many major data providers make their data available via the **World Wide Web**, a network of file servers available over the Internet.
- GIS vendors **package data** with products.

Commercial vendors





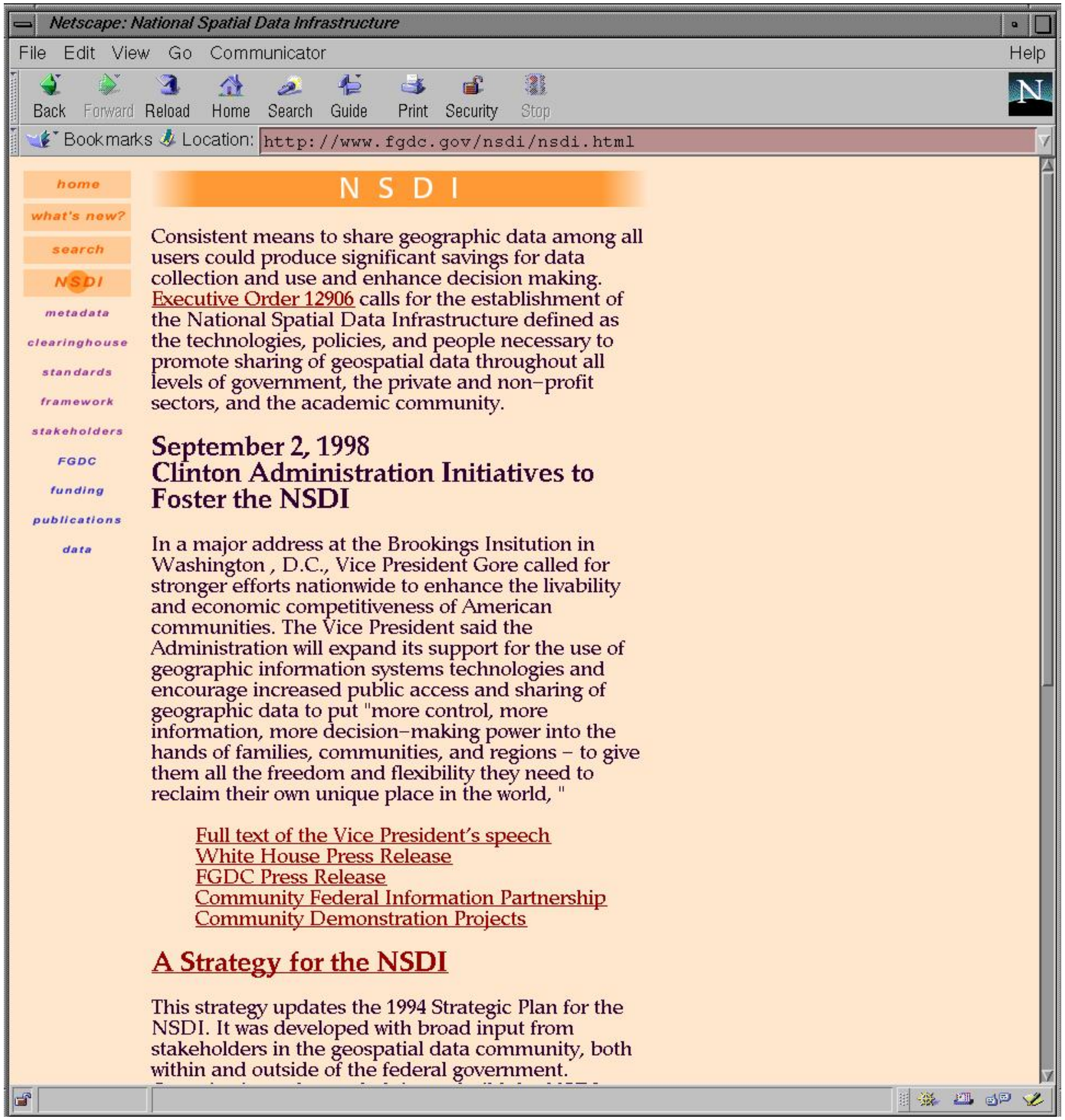
Commercial vendors

- www.navteq.com
- www.teleatalas.com
- www.geographynetwork.com
- www.google.com
- www.mapquest.com

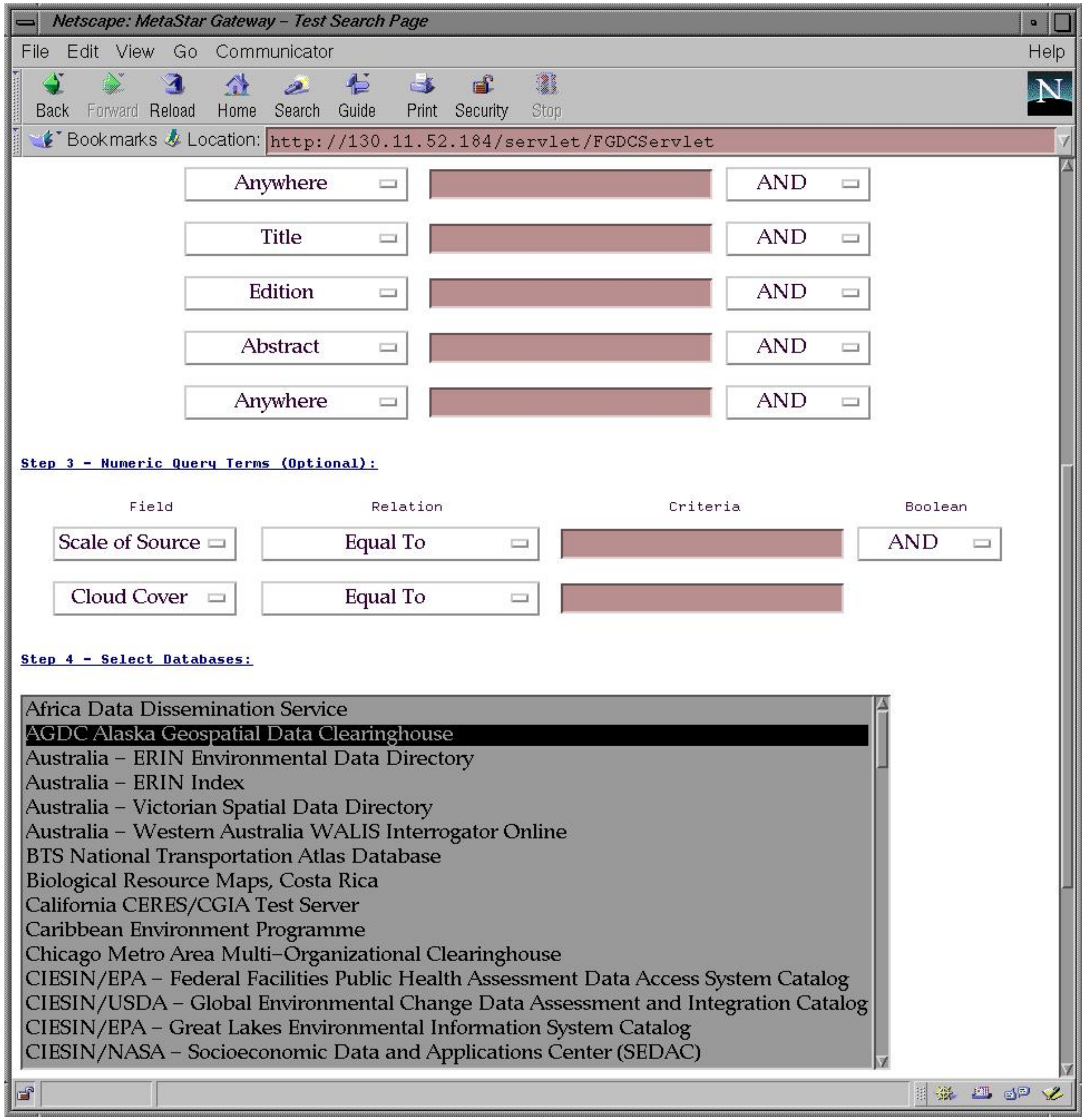
Federal Data Agencies

- USGS
- NOAA
- Census Bureau
- NIMA
- EPA
- many more...

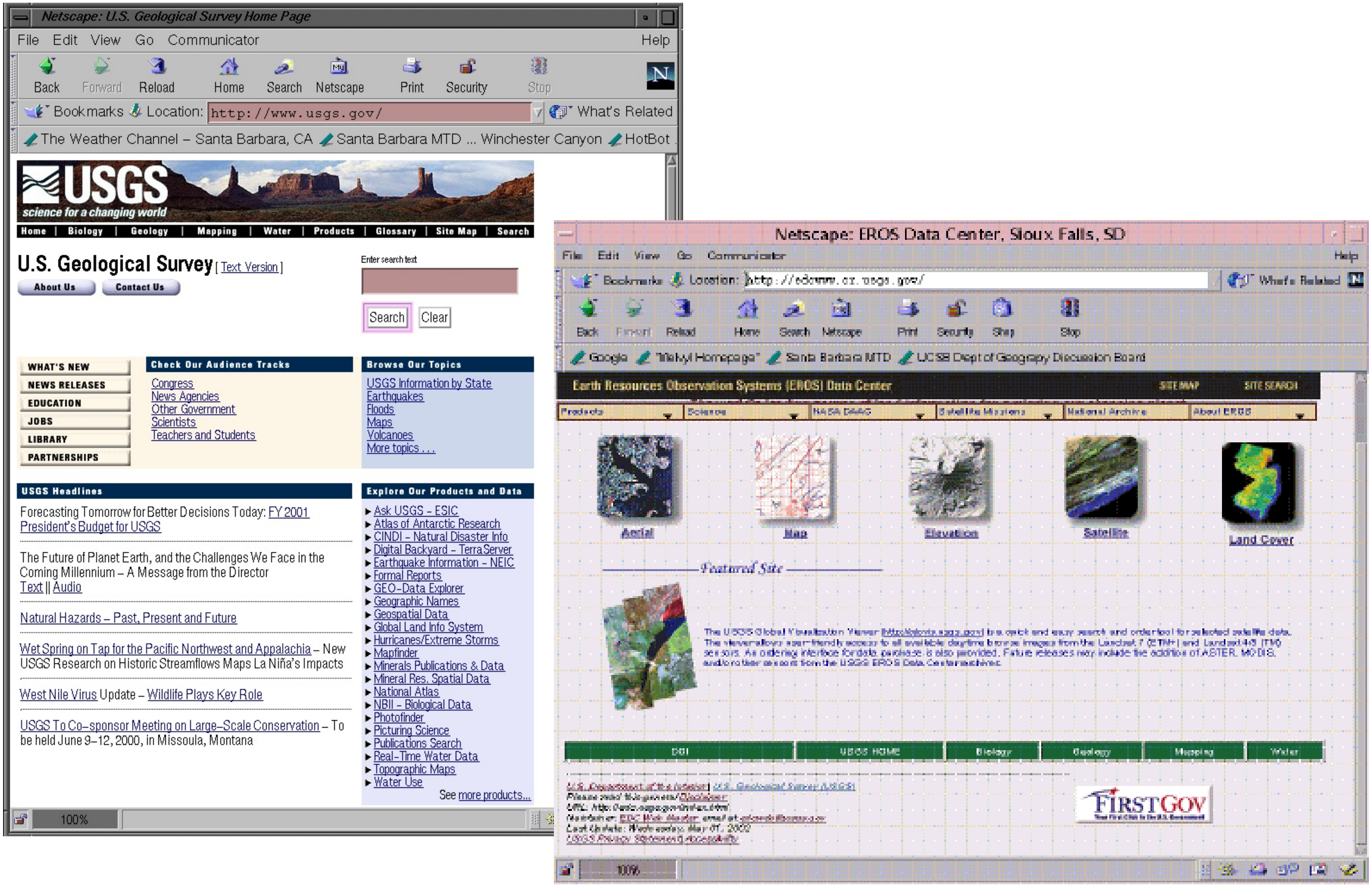
National Spatial Data Infrastructure



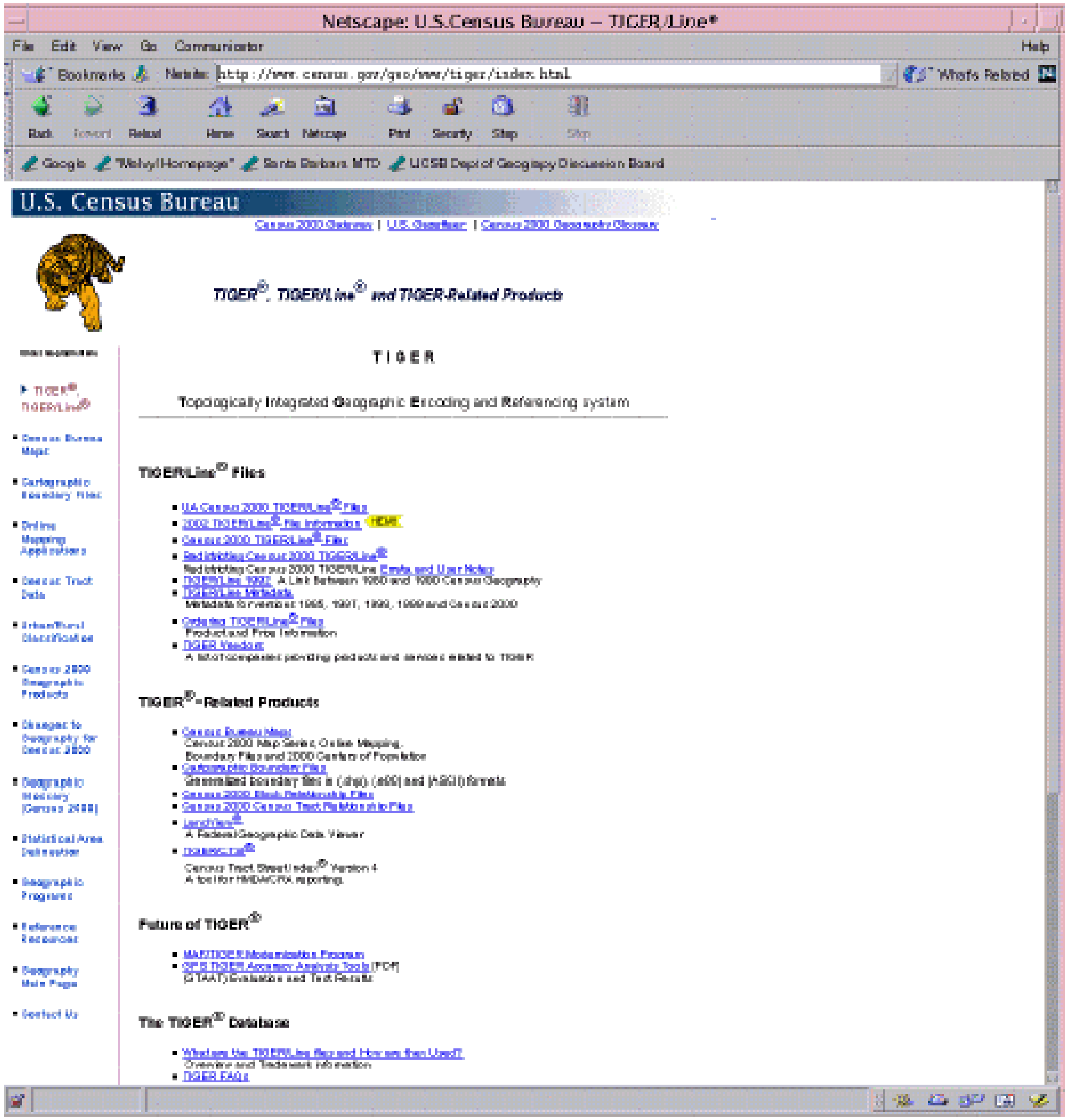
National Spatial Data Clearinghouse



USGS: National Mapping



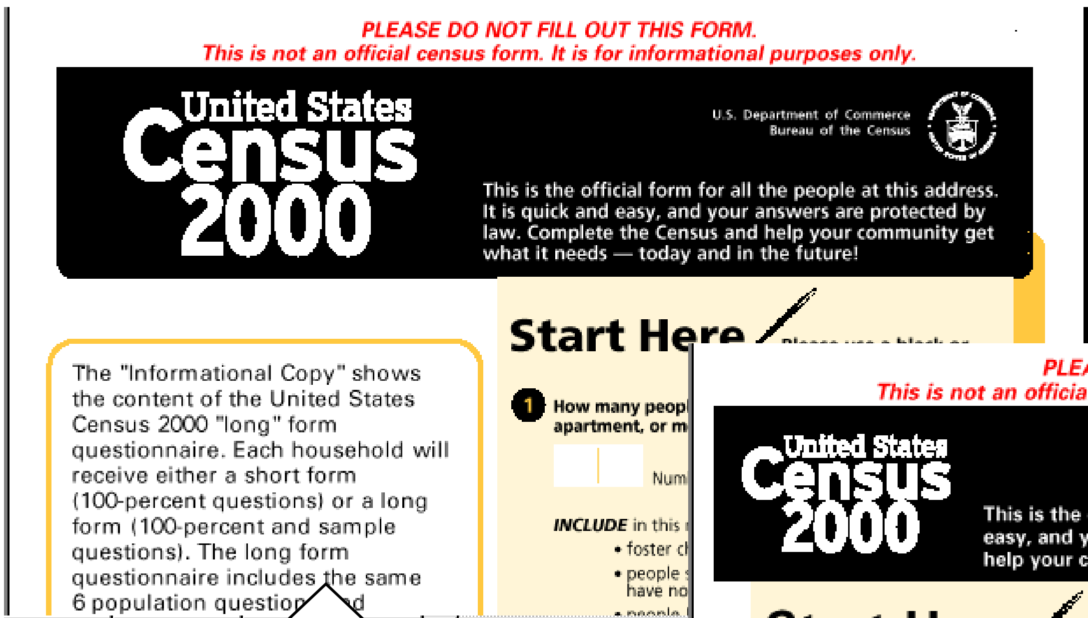
U.S. Bureau of the Census



The Decennial National Census

- This is a **survey based, national-scale** collection of data, conducted by the U.S. Census Bureau (a Federal agency) every 10 years
- This provides a snapshot of a wide range of **socio-economic data for the entire nation**, that can be used in two ways:
  - Comparisons can be made to conditions as captured by a previous census so that **change in time** can be studied **AND**
  - The data can be analyzed **spatially**, using levels of geography from local to national scales

Census 2000
Short Form and Long Form



PLEASE DO NOT FILL OUT THIS FORM.
This is not an official census form. It is for informational purposes only.

United States Census 2000

U.S. Department of Commerce
Bureau of the Census

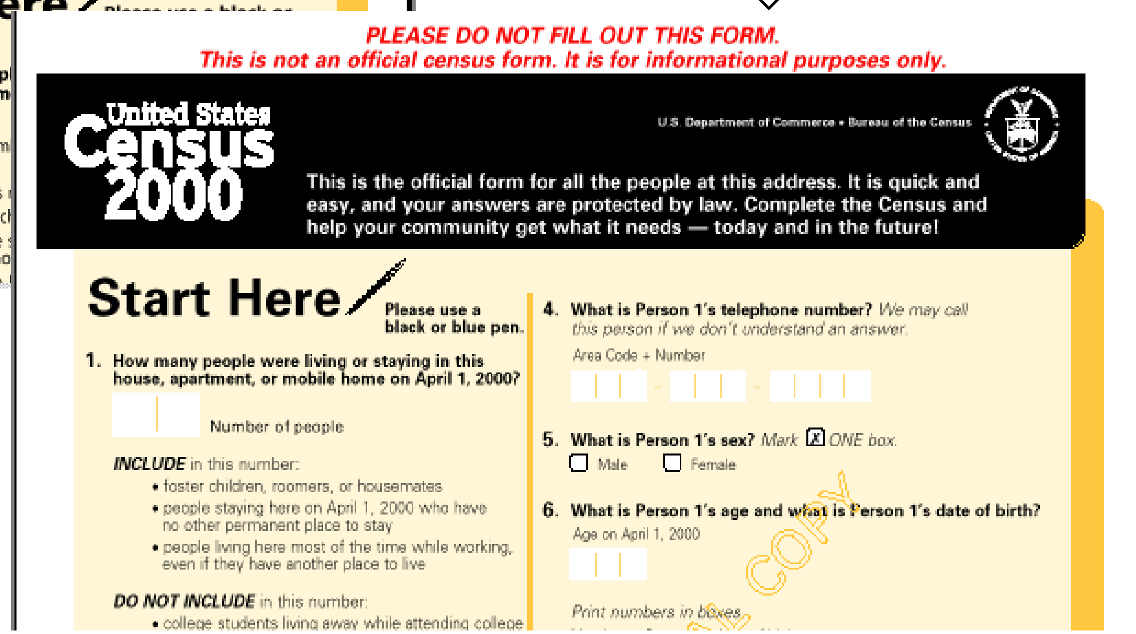
This is the official form for all the people at this address. It is quick and easy, and your answers are protected by law. Complete the Census and help your community get what it needs — today and in the future!

The "Informational Copy" shows the content of the United States Census 2000 "long" form questionnaire. Each household will receive either a short form (100-percent questions) or a long form (100-percent and sample questions). The long form questionnaire includes the same 6 population questions and

Start Here

Long form

Short form



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Start Here — Please use a black or blue pen.

1. How many people were living or staying in this house, apartment, or mobile home on April 1, 2000?

Number of people

INCLUDE in this number:
- foster children, roomers, or housemates
- people staying here on April 1, 2000 who have no other permanent place to stay
- people living here most of the time while working, even if they have another place to live

DO NOT INCLUDE in this number:
- college students living away while attending college

4. What is Person 1's telephone number? *We may call this person if we don't understand an answer.*

Area Code + Number

5. What is Person 1's sex? *Mark* ☒ *ONE box.*

☐ Male ☐ Female

6. What is Person 1's age and what is Person 1's date of birth?

Age on April 1, 2000

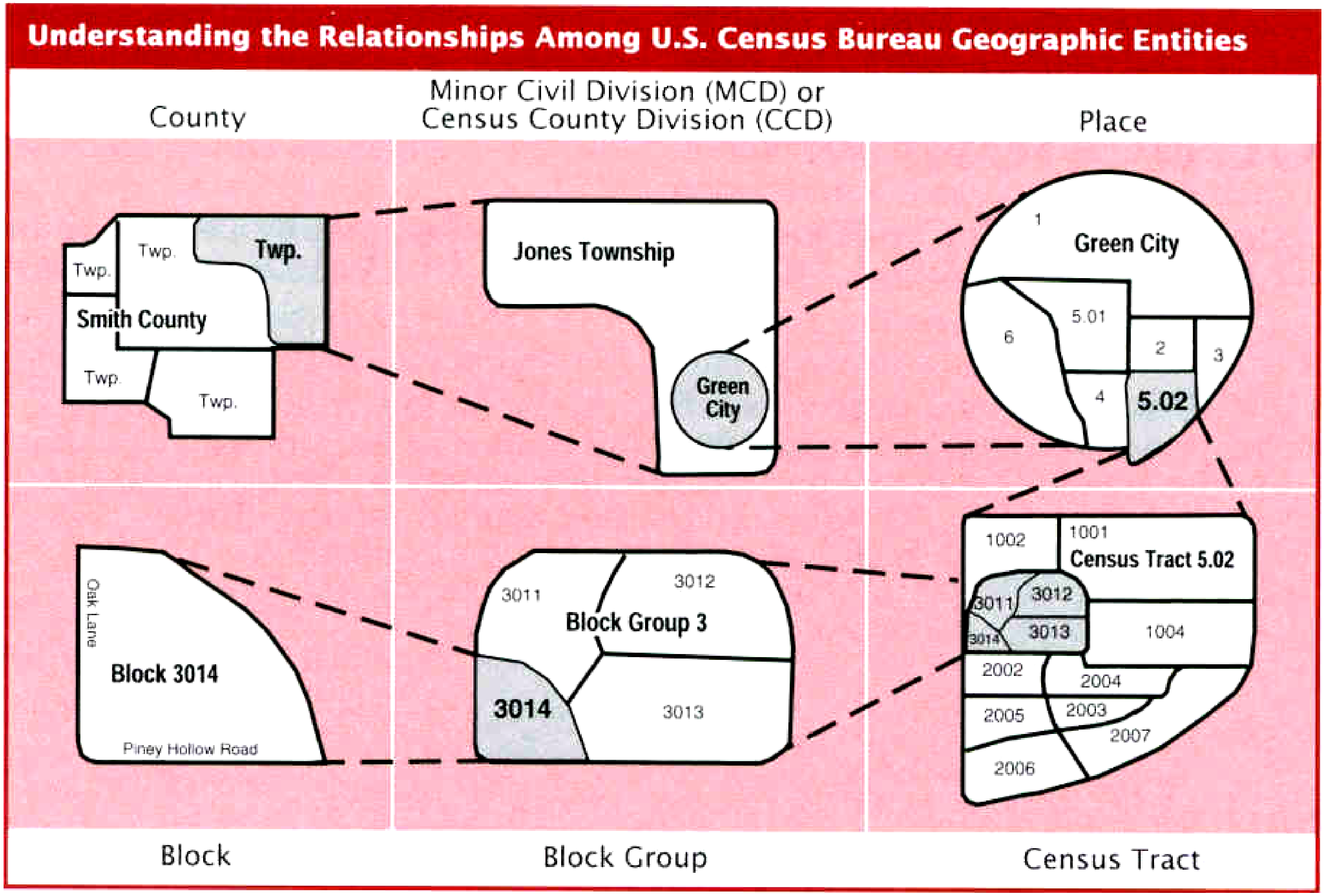
Print numbers in boxes.

Census Data as Spatial Data

- The information collected on the surveys form the **attribute part** of the data
- Individual surveys are aggregated spatially to **geographic units**, at the various levels of census geography, that uses a nested scheme that builds higher-level units out of lower ones

Small-Area Geography Overview

Census Small-Area Geography



Geographic Products: The TIGER Data Base

Topologically

Integrated

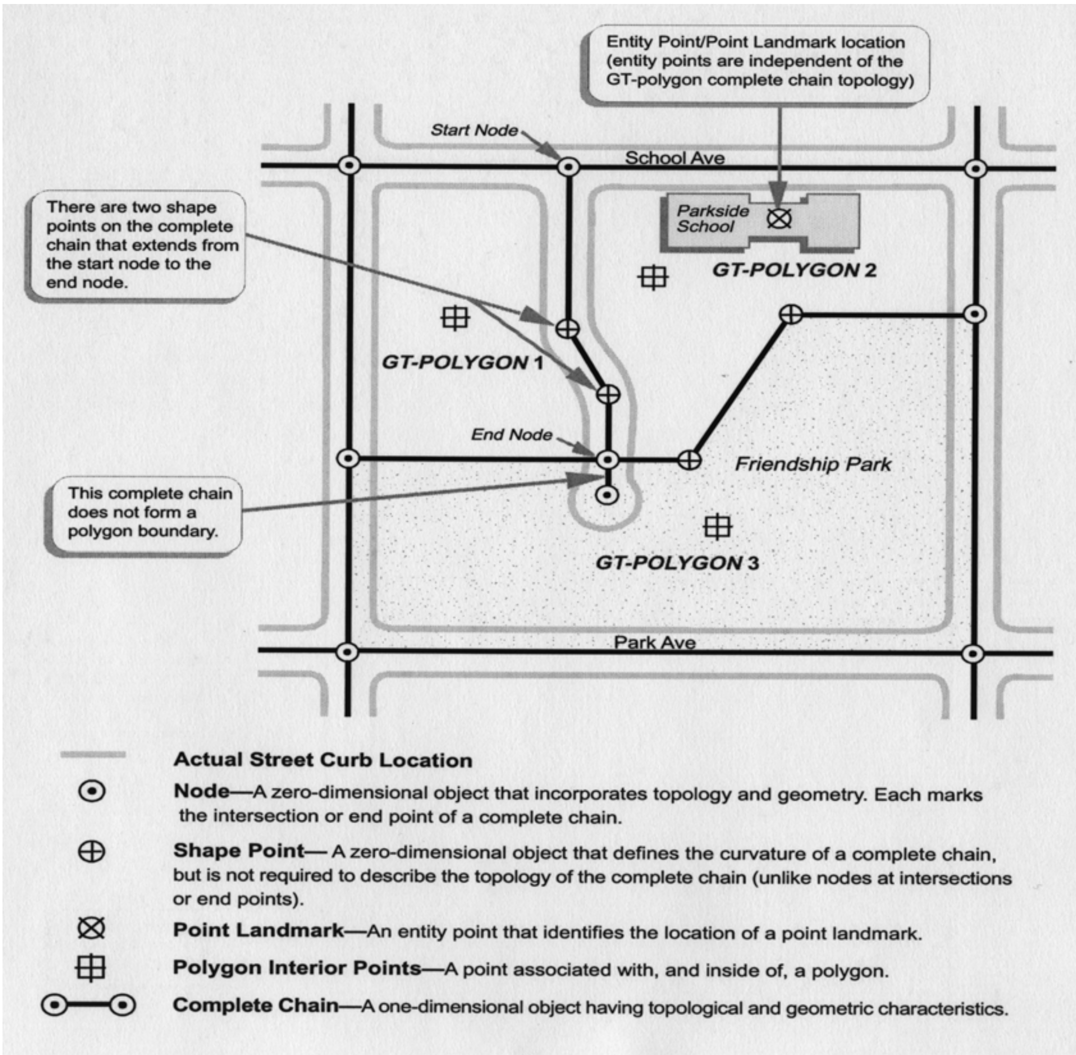
Geographic

Encoding &

Referencing

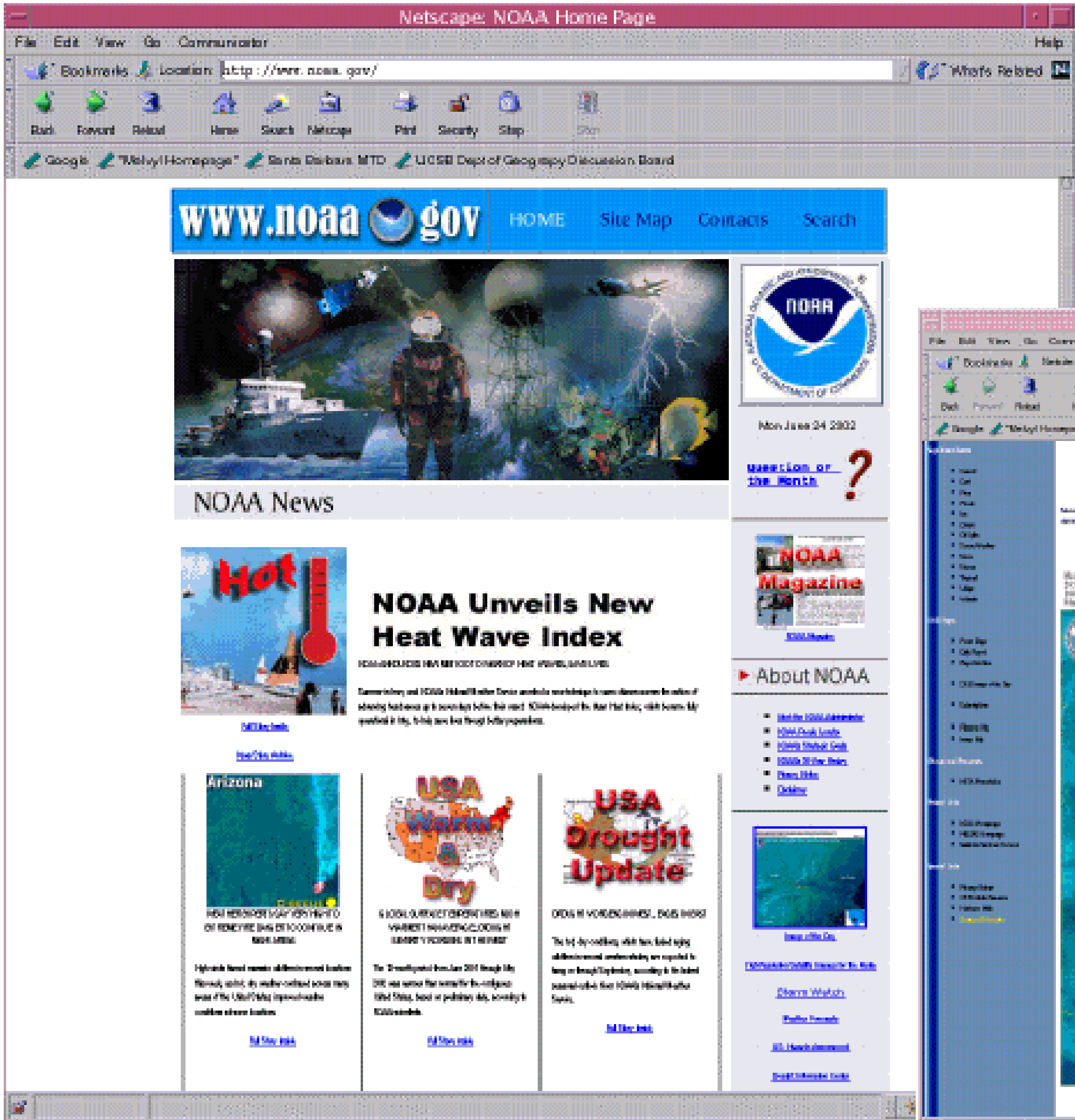
The source of **ALL** census geographic products

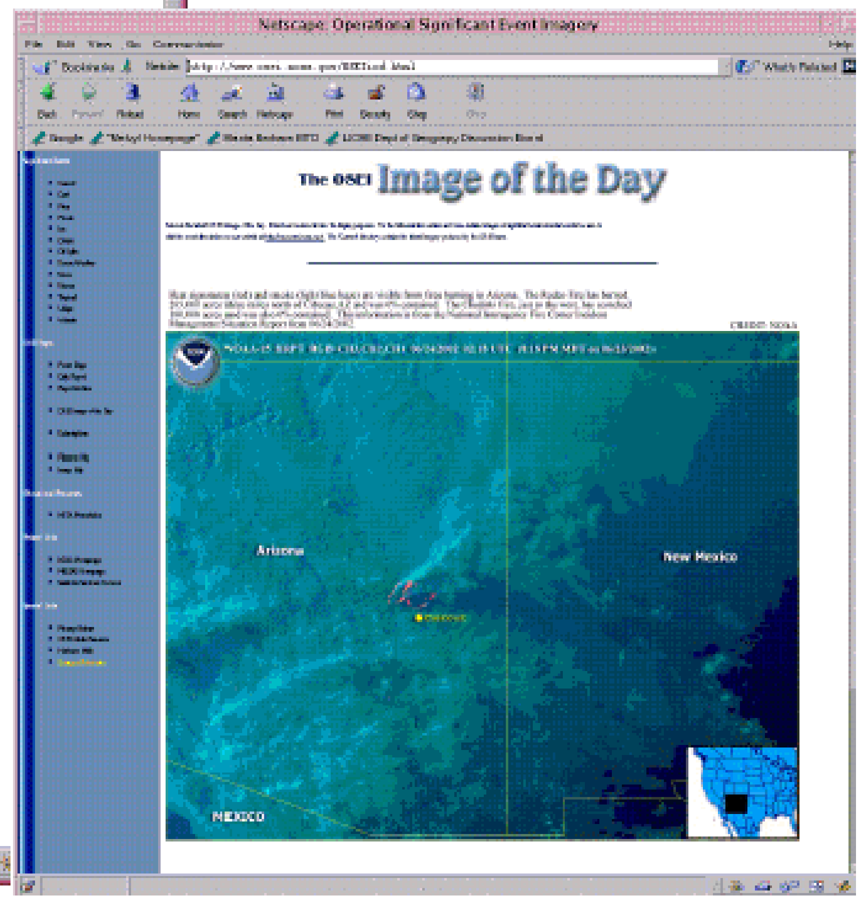
Basic TIGER/Line File Topology



One census block:
- 3 GT-polygons
- 1 point landmark (school)
- 1 area landmark (park)

NOAA Weather and other data

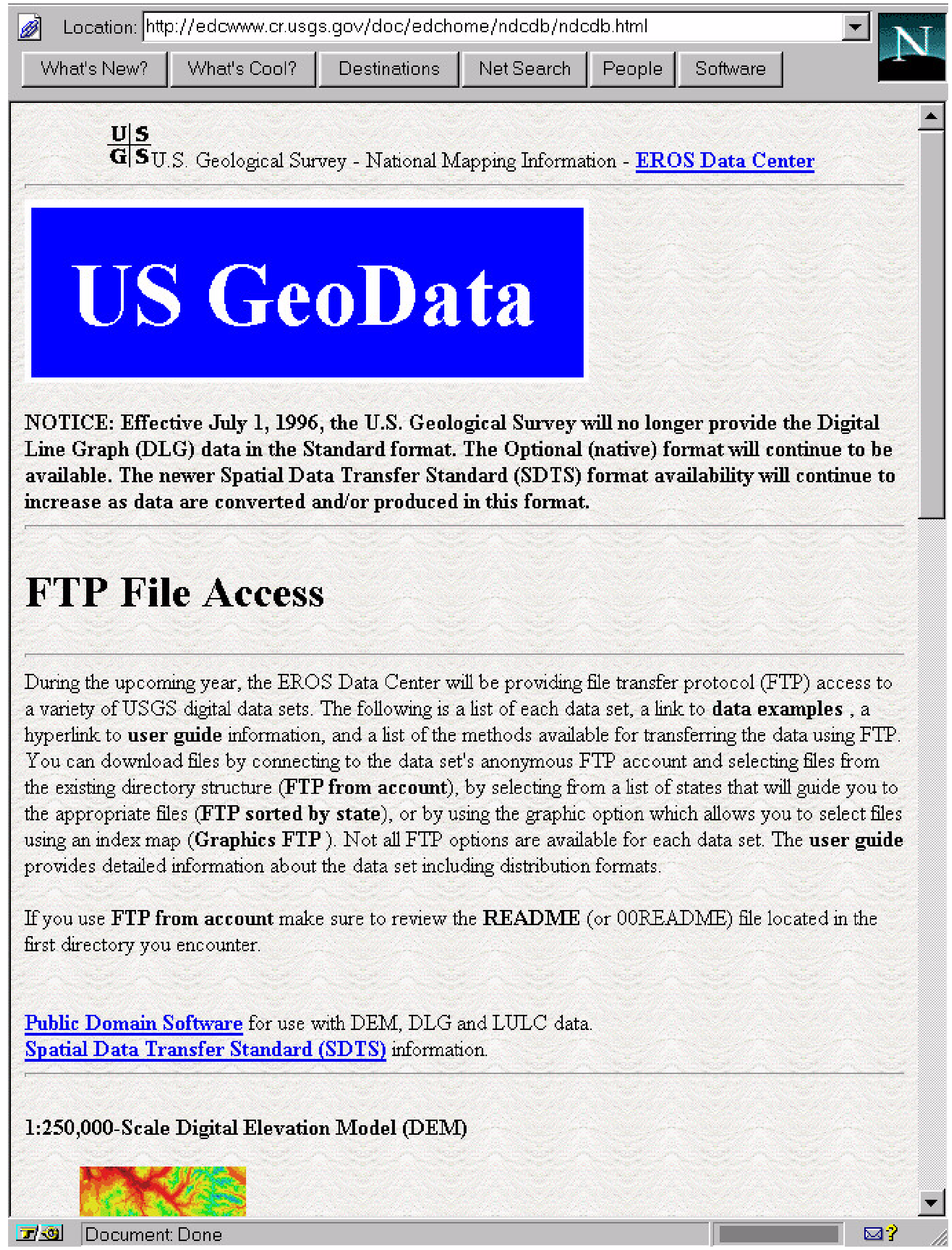




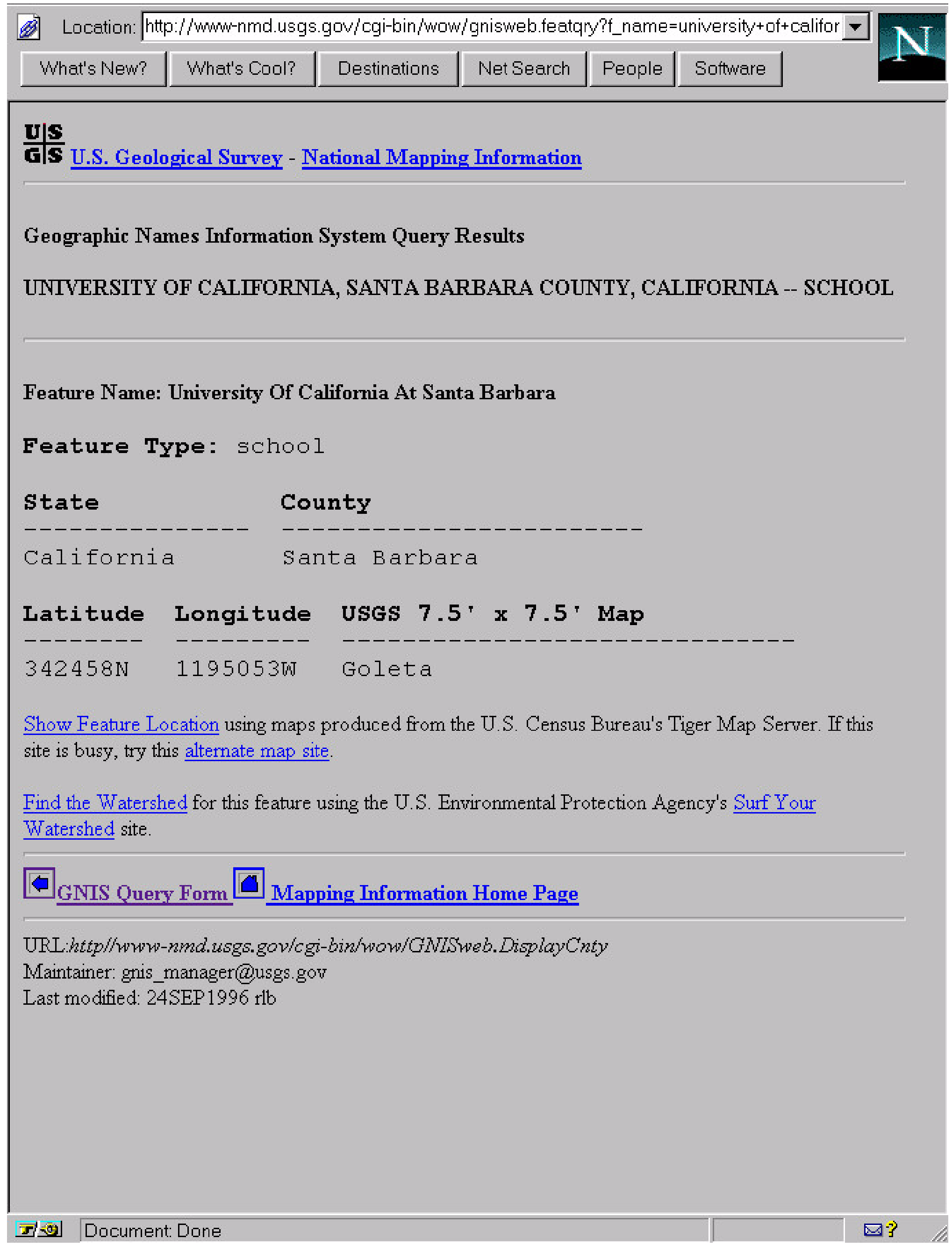
Eros Data Center

- Distributed active archive center
- Sioux Falls, SD
- Operated by USGS

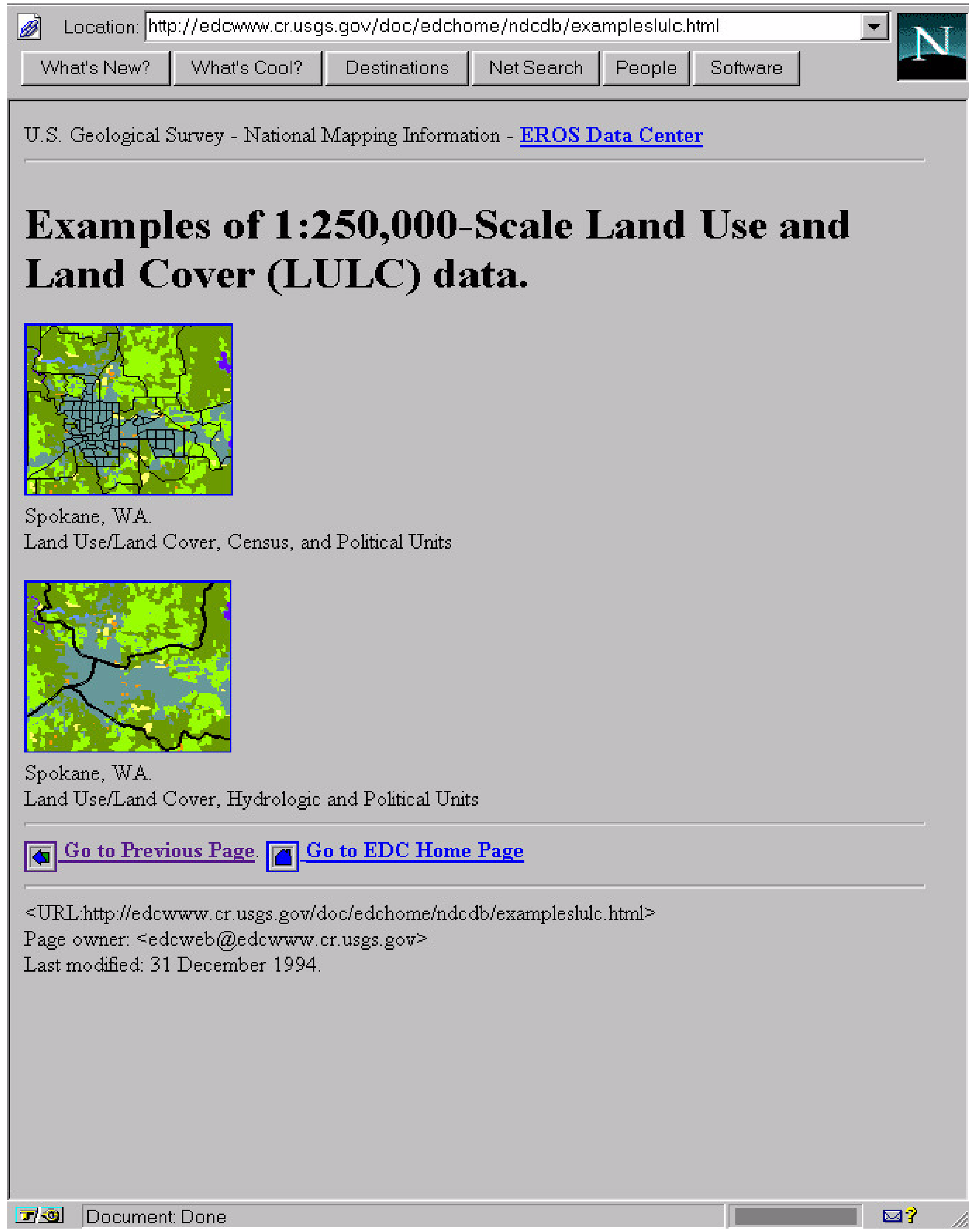
US GeoData ftp access to DEM DLG GNIS GIRAS etc.



GNIS Feature locations



GIRAS Land Use and Land Cover Data


Location: http://edcwww.cr.usgs.gov/doc/edchome/ndcdb/exampleslulc.html

What's New? What's Cool? Destinations Net Search People Software

U.S. Geological Survey - National Mapping Information - EROS Data Center

Examples of 1:250,000-Scale Land Use and Land Cover (LULC) data.

Spokane, WA.
Land Use/Land Cover, Census, and Political Units

Spokane, WA.
Land Use/Land Cover, Hydrologic and Political Units

Go to Previous Page. Go to EDC Home Page

<URL:http://edcwww.cr.usgs.gov/doc/edchome/ndcdb/exampleslulc.html>
Page owner: <edcweb@edcwww.cr.usgs.gov>
Last modified: 31 December 1994.

Document: Done

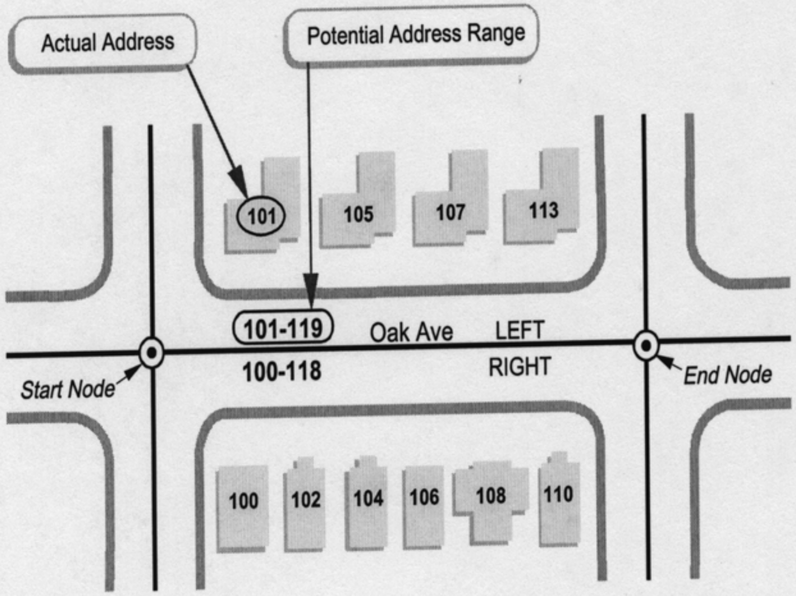
GEOCODING

- Geocoding is the **conversion of spatial information** into **digital form**
- Geocoding involves **capturing the map**, and sometimes also **capturing the attributes**
- Often involves **address matching**

Address Matching

- Most GISs contain capability for **address matching**
- **Start with** 100 Morrissey Boulevard, Boston, MA 02125
- **End with** coordinates (lat-long for UMB)
- May need to **interpolate along blocks**
- Street number range, **left and right side** e.g. 101-199

TIGER/Line Address Range Basics



Record Type 1 contains separate data fields for both the start and end of each address range.

Record Type 1 — **Address Range**

				Left side		Right Side	
				Start	End	Start	End
RT	TLID	FENAME	FETYPE	FRADDL	TOADDL	FRADDR	TOADDR
1	0007654320	Oak	Ave	101	119	100	118

The complete chain has two address ranges:
left: odd-numbered
right: even-numbered.

Potential address ranges along a complete chain have values that encompass the addresses of existing structures, as well as those not yet built

GEOCODING LEAVES A "STAMP" ON DATA

- The **method** of geocoding can influence the **structure and error** associated with the spatial information which results
- **Examples**: scanning (raster), digitizing (vector)

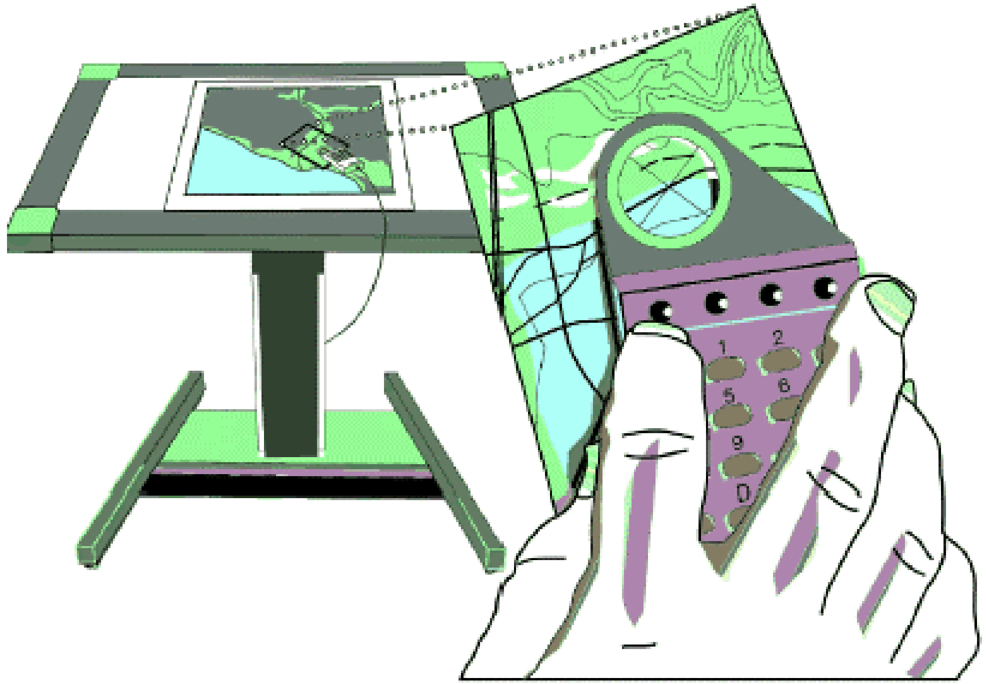
Geocoding methods for maps

- Digitizing
- Scanning
- Field data collection

Digitizing

- Captures map data by **tracing lines** from a map by hand
- Uses a cursor and an electronically-sensitive **tablet**
- Result is a **string of points** with (x, y) values

The Digitizing Tablet



1. Digitizer cursor transmits a pulse from an electromagnetic coil under the view lens.
2. Pulse is picked up by nearest grid wires under tablet surface.
3. Result is sent to computer after conversion to x and y units.

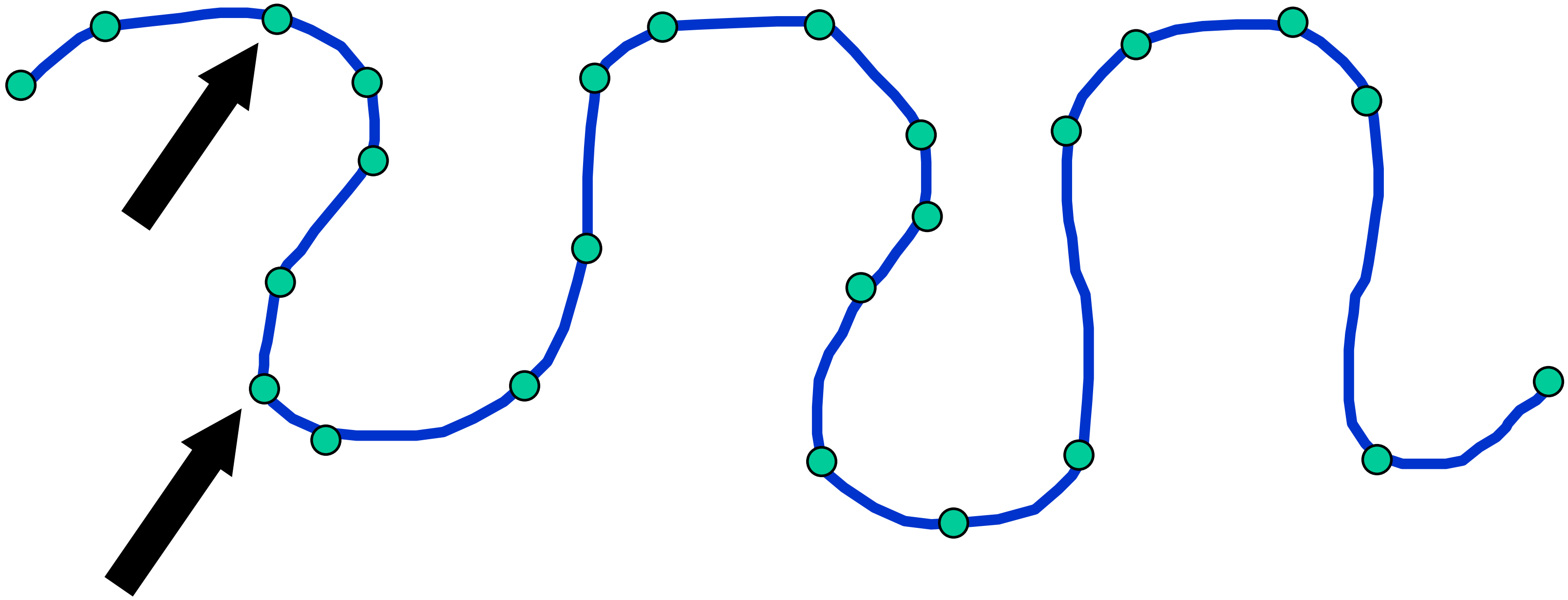
Digitizing

- Stable base map
- Fix to tablet
- Digitize control
- Determine coordinate transformation
- Trace features
- Proof plot
- Edit
- Clean and build

Digitizing

- Cursor data entry
- Secondary tablet (menu/template)
- Voice command entry
- Point select
- Stream mode
- Distance mode

Selecting points to digitize



Some common digitizing errors

- Slivers
- Duplicate lines
- Duplicate nodes
- Unended lines
- Gaps
- Zingers

Scanning

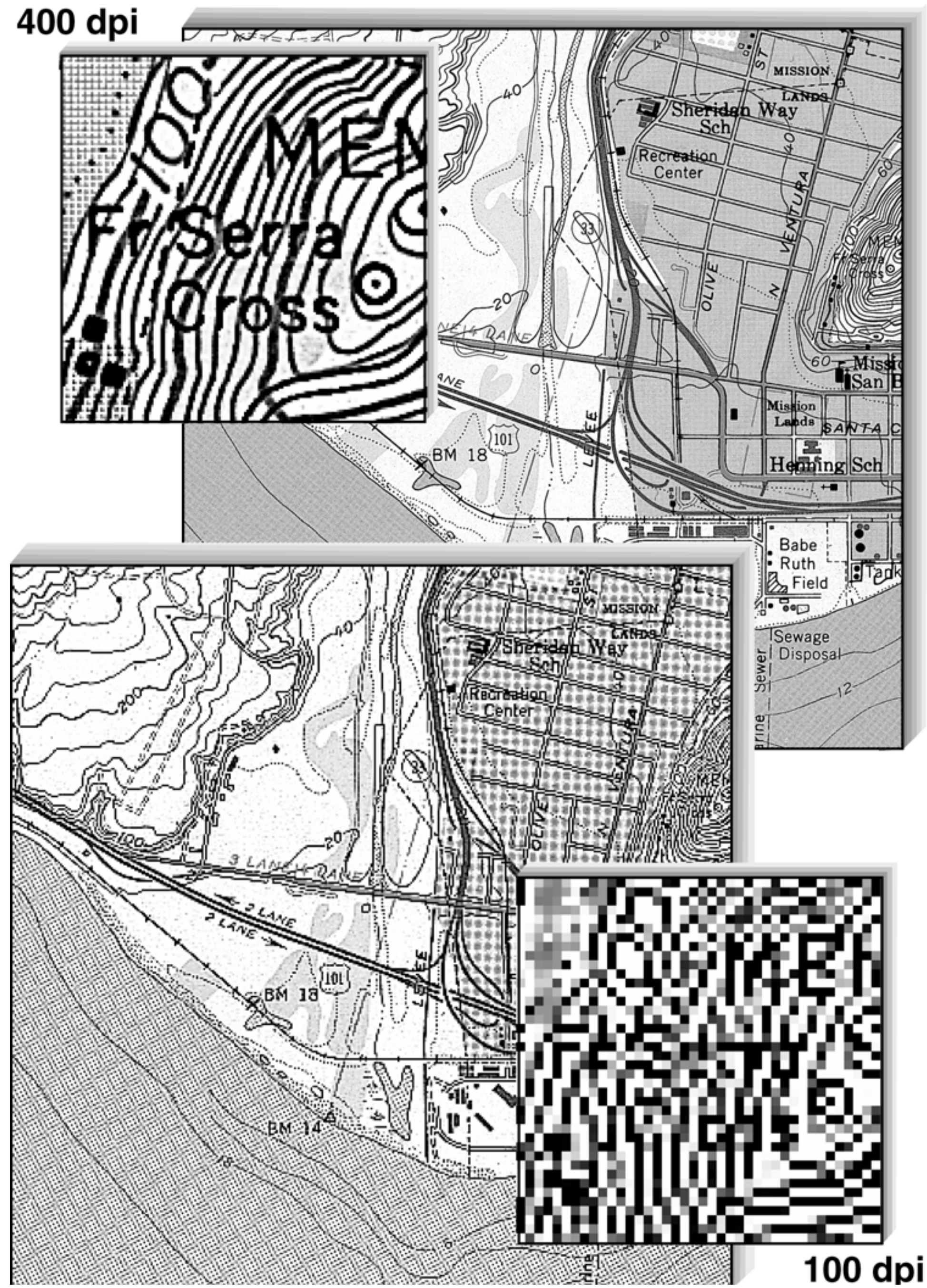
- Places a **map on a glass plate**, and passes a **light beam** over it
- Measures the **reflected light** intensity
- Result is a **grid of pixels**
- **Image size** and **resolution** are important
- Features can **"drop out"**

Scanning

- **Types** of scanners:
  – Flat bed vs. Drum
- **Characteristics**
  – DPI & File size

Scanning example

- 15 x 15 cm (3.6 x 3.6 km)
- grid is 0.25 mm
- ground equivalent is 6 m
- 600 x 600 pixels
- one byte per color (0-255)
- 1.08 MB



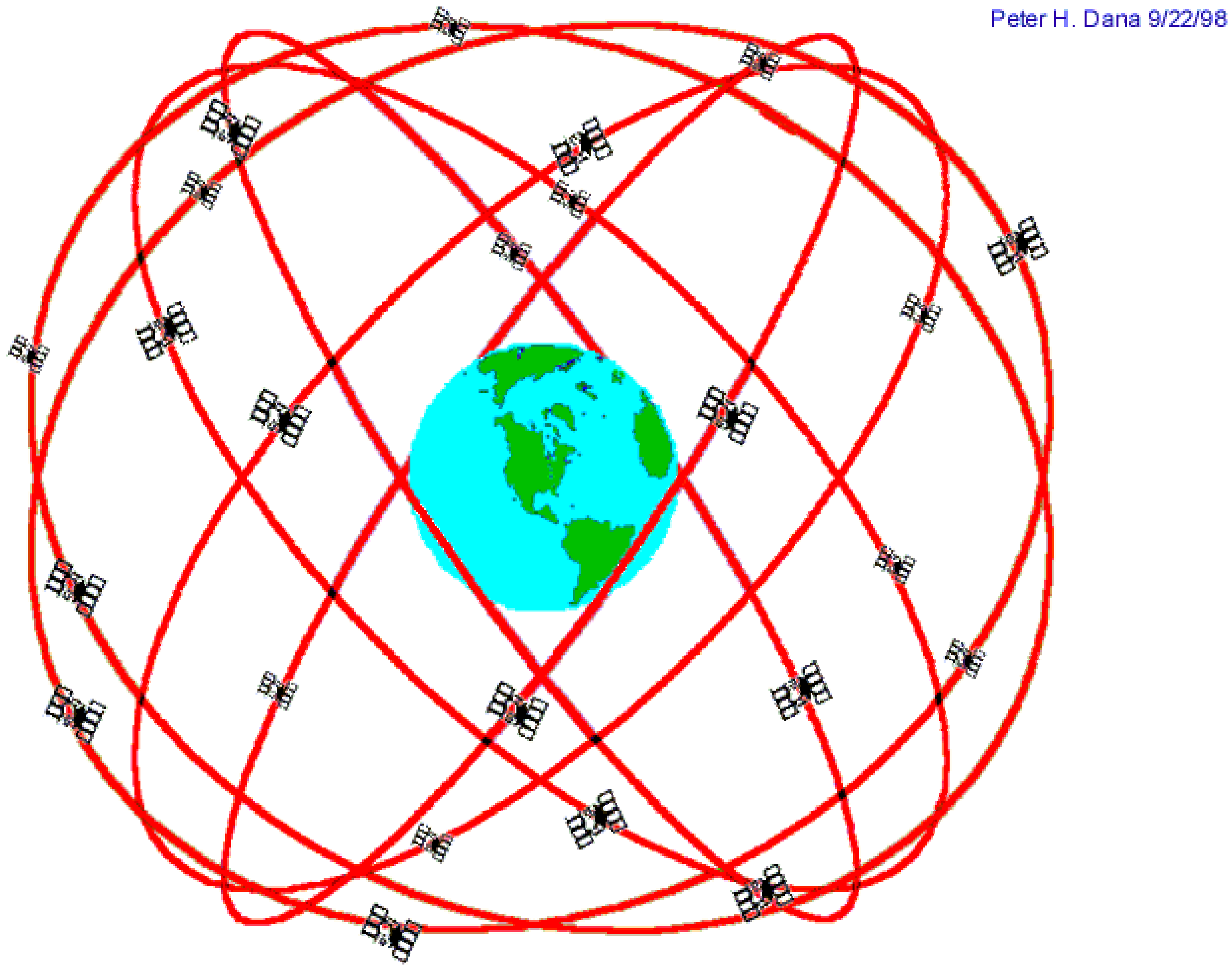
Field data collection

Global Positioning System (GPS)

- A space-based 3-dimensional **measurement and positioning system** that operates using radio signals from satellites orbiting the earth
- Created and maintained by the US Dept. of Defense and the US Air Force
- The system as a whole consists of three **segments**:
  - satellites (space segment)
  - receivers (user segment)
  - ground stations (control segment)
- Note: Russia and a European consortium are implementing similar systems.

GPS – Space Segment (Satellites)

- **24 NAVSTAR satellites** in the GPS constellation
  - orbit the Earth **every 12 hours**
  - ~11,000 miles altitude (a very **high orbit**)
  - positioned in **6 orbital planes** (4 per plane)
  - orbital period & planes are designed to keep **4-6 satellites above the horizon** at any time everywhere on the planet
  - controlled and monitored by five ground stations around the globe

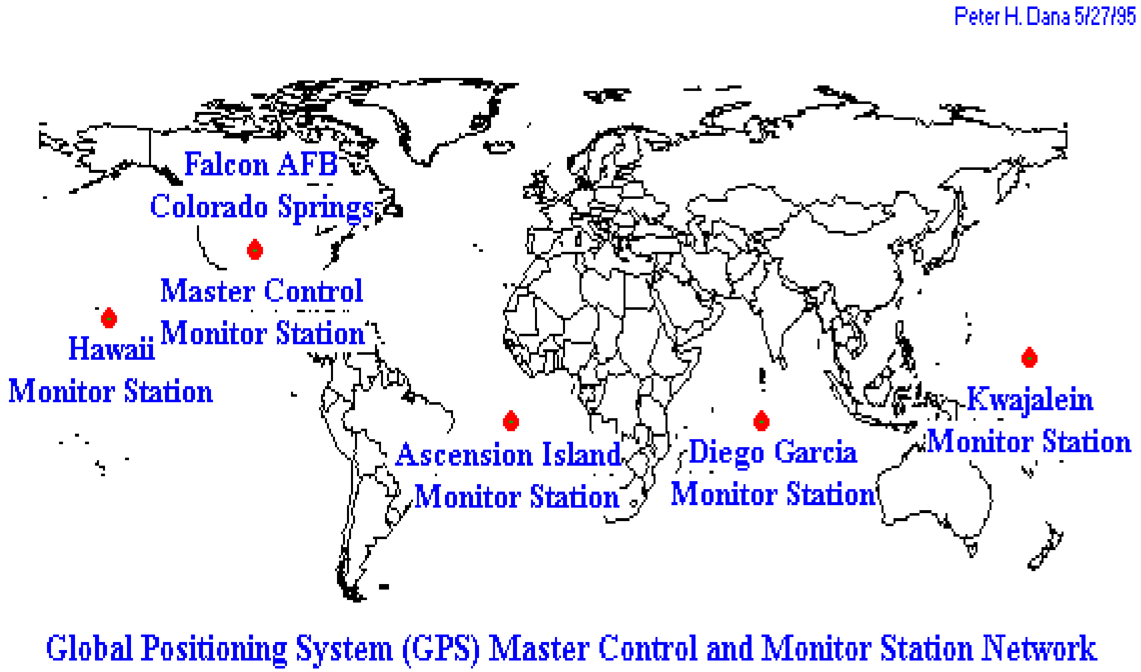


GPS Nominal Constellation
24 Satellites in 6 Orbital Planes
4 Satellites in each Plane
20,200 km Altitudes, 55 Degree Inclination

GPS – User Segment (Receivers)

- Ground-based devices that can read and **interpret the radio signals** from several of the NAVSTAR satellites at once
- Use **timing** of radio signals to calculate the receiver's **position** on the Earth's surface
- Calculations result in varying **degrees of accuracy** that depend on:
  - quality of the receiver
  - user operation of the receiver
  - local & atmospheric conditions
  - current status of system

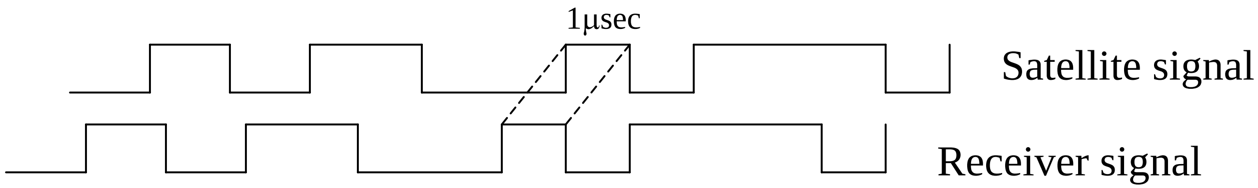
GPS – Control Segment (Ground Stations)



- Five control stations
  - master station at Falcon (Schriever) AFB, Colorado
  - **monitor** satellite orbits & clocks
  - **broadcast** orbital data and clock **corrections** to satellites

GPS - How Does it Work?

- GPS allows us to determine a position by calculating the **distance** between a receiver and multiple satellites
  - Distance is determined by **timing** how long it takes the signal to travel from satellite to receiver
  - Radio signals travel at **speed of light**: 186,000 mi / sec
  - Satellites and receivers generate **exactly the same signal** at exactly the same time
  - Signal travel time = delay of satellite signal relative to the receiver signal

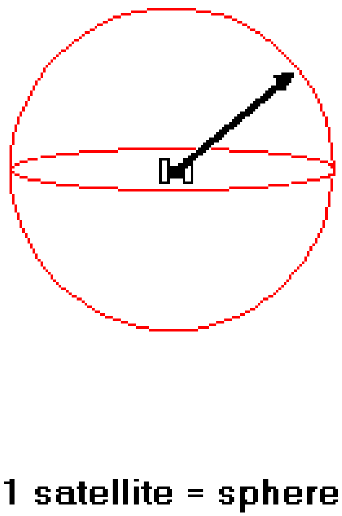


GPS - Satellite Signals

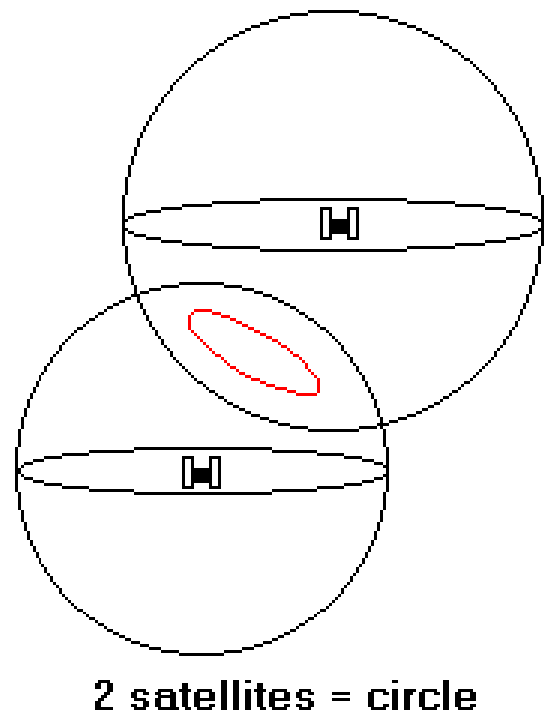
- Satellites have accurate **atomic clocks** and all 24 satellites are transmitting the same time signal at the same time
- The satellite signals contains information that includes
  - Satellite number
  - Time of transmission
- Receivers use an **almanac** that includes
  - The **position** of all satellites every second
  - This is updated monthly from control stations
- The satellite signal is received, compared with the receiver's internal clock, and used to calculate the **distance** from that satellite
- **Trilateration** (similar to triangulation) is used to determine location from multiple satellite signals

GPS - Trilateration

Start by determining the distance between a single GPS satellite and your position (**a sphere**)

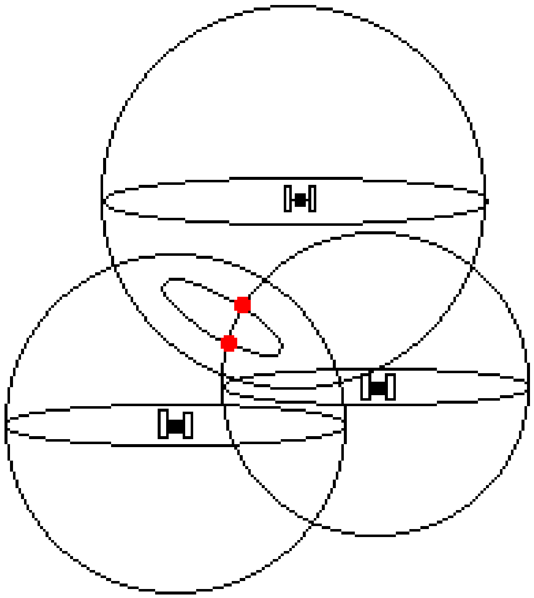


Adding a second distance measurement to another satellite narrows down your possible positions to **a circle** where the spheres intersect

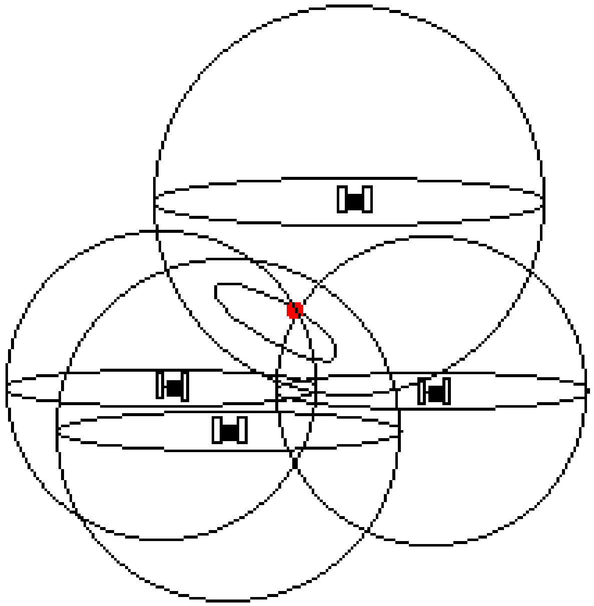


GPS - Trilateration Cont.

Adding a third satellite narrows down the position to **two points** where the three sphere intersect, and usually only one point is a **'reasonable'** answer



3 satellites = 2 points



4 satellites = 1 point

The intersection of four spheres occurs at **one point**, but the 4th measurement is not needed, and is used for **timing** purposes instead

GPS - Using the 4th Signal

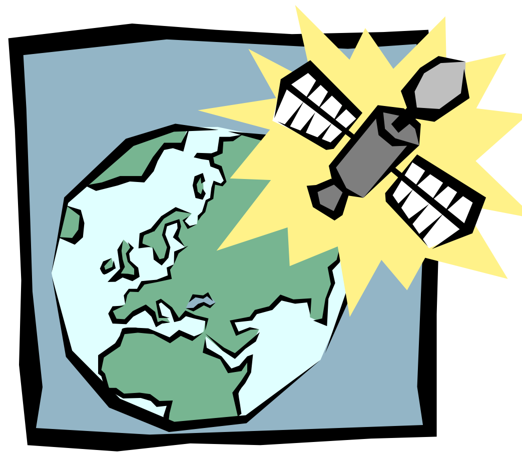
- How do we know that satellites and receivers generate the **same signal** at the **same time**?
  - The satellites have **atomic clocks**, so we know they are accurate
  - But **receivers do not** -- so can we ensure they are exactly accurate? No! If the receiver's timing is off, the location in 3-D space will be off slightly...
- So: We use the 4th satellite to **resolve any signal timing error** instead by
  - determining a **correction factor** using the 4th satellite
  - (like solving multiple equations ... there will only be one solution that satisfies all equations)

GPS - Sources of Error

- Satellite errors
  - satellite position / orbit error
  - satellite clock error
- Atmospheric errors
  - Speed of electromagnetic waves in the atmosphere
  - Path taken by the signal
- Multi-path distortion errors
- Receiver errors
- (Selective availability)

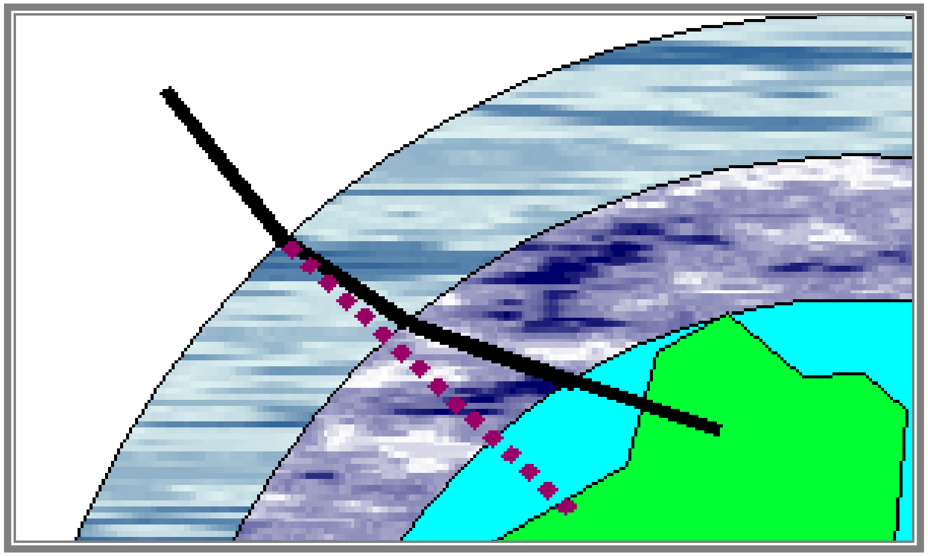
GPS - Sources of Error

- Satellite Errors
  - Although the satellites are in high orbits to minimize their deviations, sometimes there is a slight **'wobble'** due to local gravitational forces
  - While the atomic clocks used in the satellites are extremely accurate (and quadruple redundant), sometimes clock errors can occur
- These can contribute up to **1-5 meters** of error



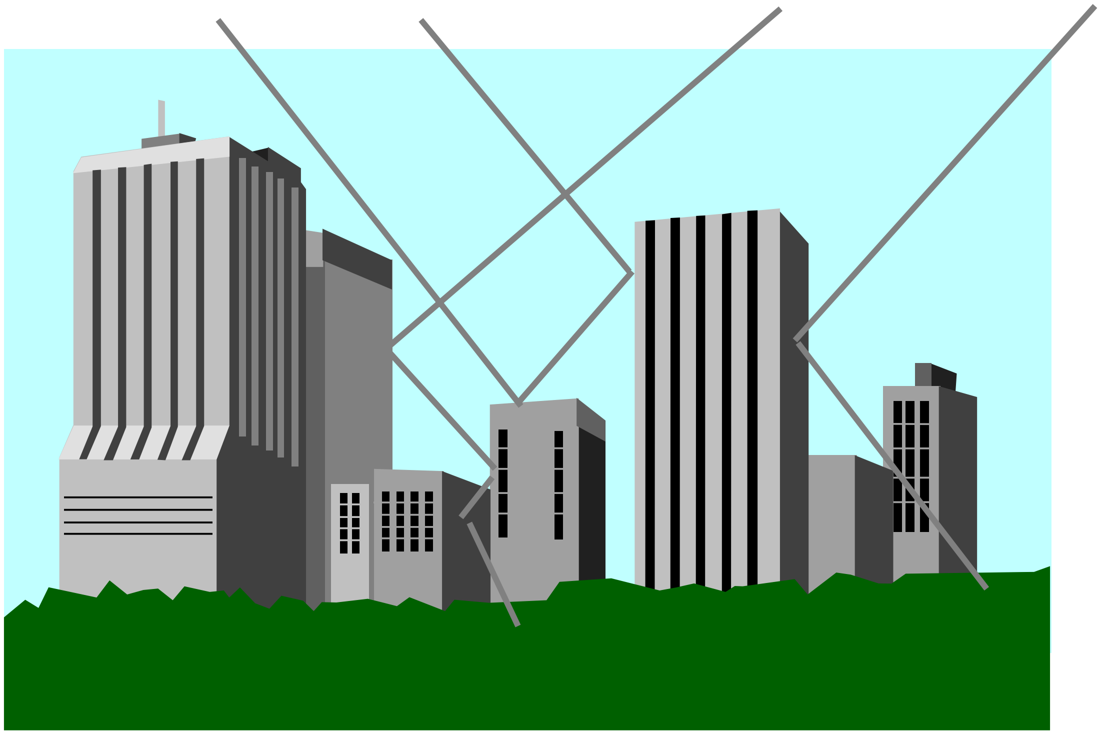
GPS - Sources of Error

- Atmospheric Delays/Bending
  - The speed of light is only precisely 186,000 miles per second in a vacuum, and is slightly **slower in the atmosphere**, varying by composition
  - The signal can be **bent** as it moves through the atmosphere (sphere size based on a straight path)
- **Up to 30m** of error



GPS - Sources of Error

- Multi Path Interference
  - The signal can **bounce off** of buildings, trees, etc. and this again distorts the time and distance between the receiver and the satellite
- **Up to 1m** of error

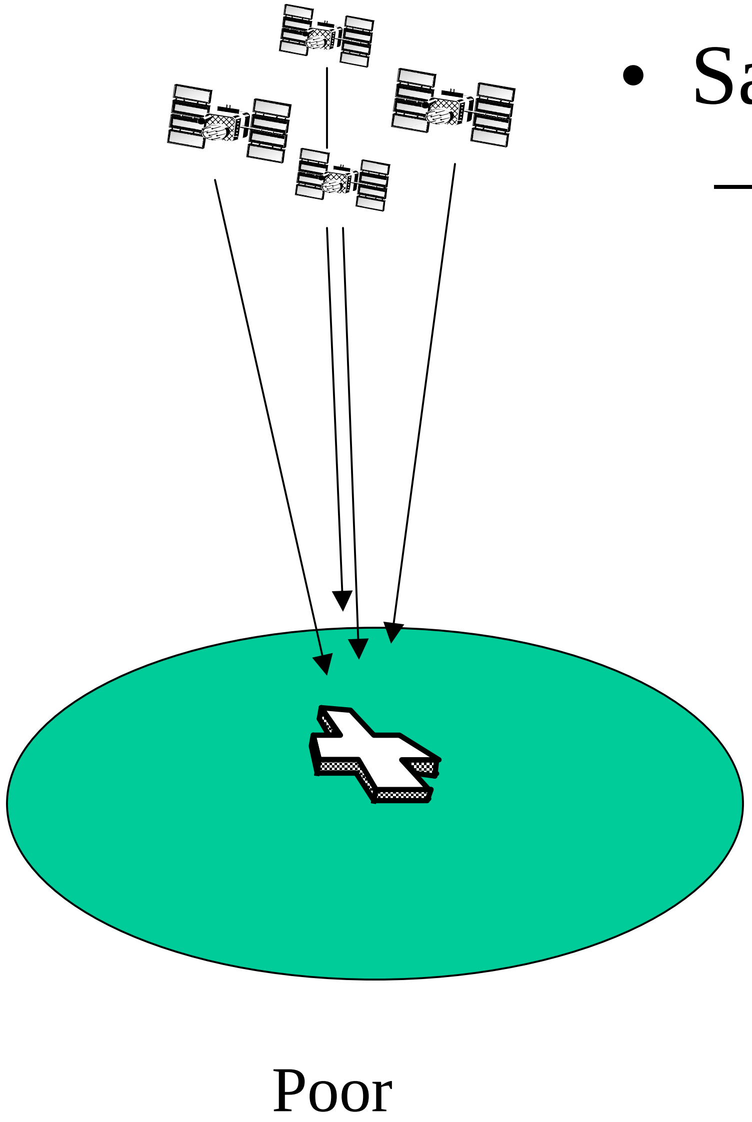


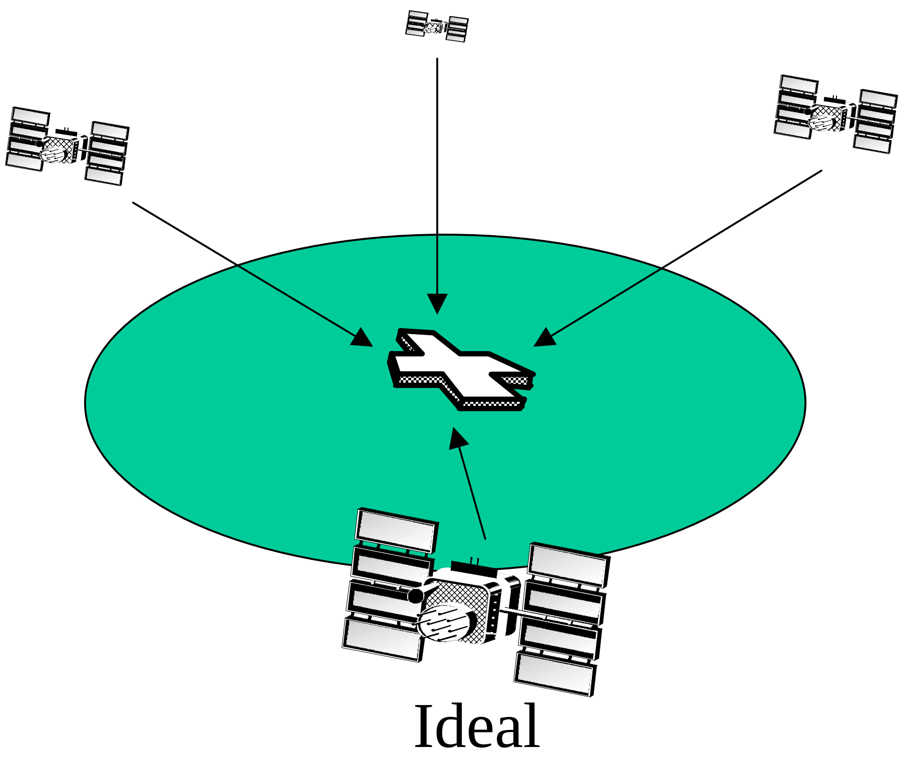
GPS - Sources of Error

- Receiver Errors (Timing/Rounding)
  - Satellites have quadruple redundant atomic clocks that are **accurate to nanoseconds** (about $800,000 of clock hardware on each satellite), e.g. "the time is 2:02:01.23456789012"
  - Receivers are powered by 4 AA batteries worth about $2.99, generate their clock signal with an oscillating crystal that is sensitive to battery current, e.g. "the time is 2:02:01.2345"
- **Up to 10 meters** of error

GPS - Sources of Error

- Satellite Coverage in Sky
  - Position Dilution of Precision **(PDOP)**





The Role of Error

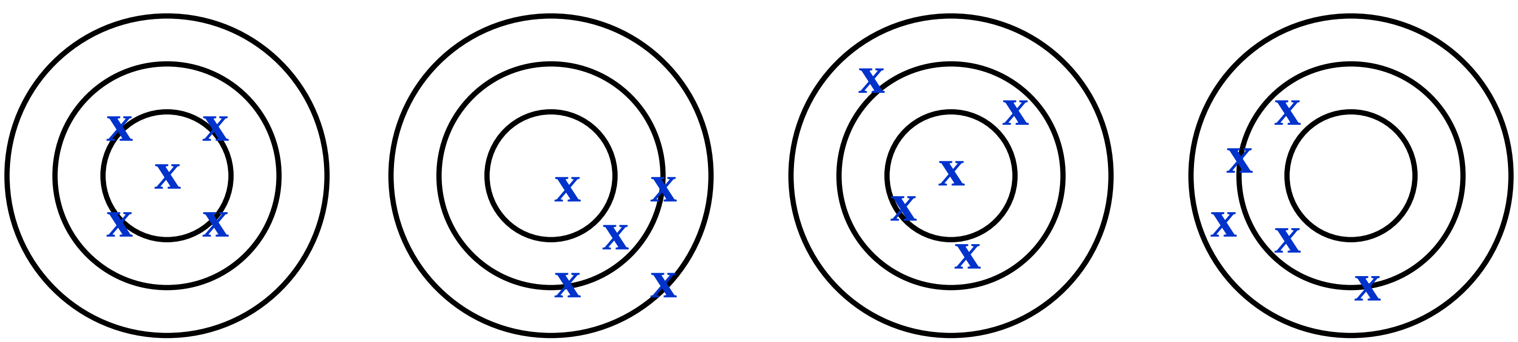
- **Enforcement** for map data is usually by **using topology**
- Map and attribute data errors are the **data producer's responsibility**, but the GIS user must understand error
- **Accuracy and precision** of map and attribute data in a GIS **affect all other operations**, especially when maps are compared across scales

Precision and Accuracy

- When describing error we need to distinguish between **two characteristics**:
  - **Accuracy** refers to the **amount of distortion** from the true value in a measurement
  - Precision refers to the **variation among repeated measurements**, and also to the **amount of detail** in the reporting of a measurement

Precision and Accuracy

- These related concepts are often confused:
  - **Precision** refers to the exactness associated with a measurement (i.e. closely clustered)
  - **Accuracy** refers to the extent of systematic bias in the measurement process (i.e. centered on the middle)



Precise & Accurate | Precise & Inaccurate | Imprecise & Accurate | Imprecise & Inaccurate

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Next Topic:

What is where?