Deck 5: Global Positioning System

Projections Recap, Practical Exam Info, GPS, Selections vs. Geoprocessing

Intro to GIS – UMass Amherst – Michael F. Nelson

Request Azure Virtual Desktop Now!!!

- Do it!
- Azure Virtual Desktop at UMass Amherst | UMass Amherst Information Technology | UMass Amherst

- Do not wait, you may find yourself in a serious bind if the lab computers fail during midterm week!
- This is your final warning – there will be no extensions granted on the midterm due to lack of virtual desktop access!

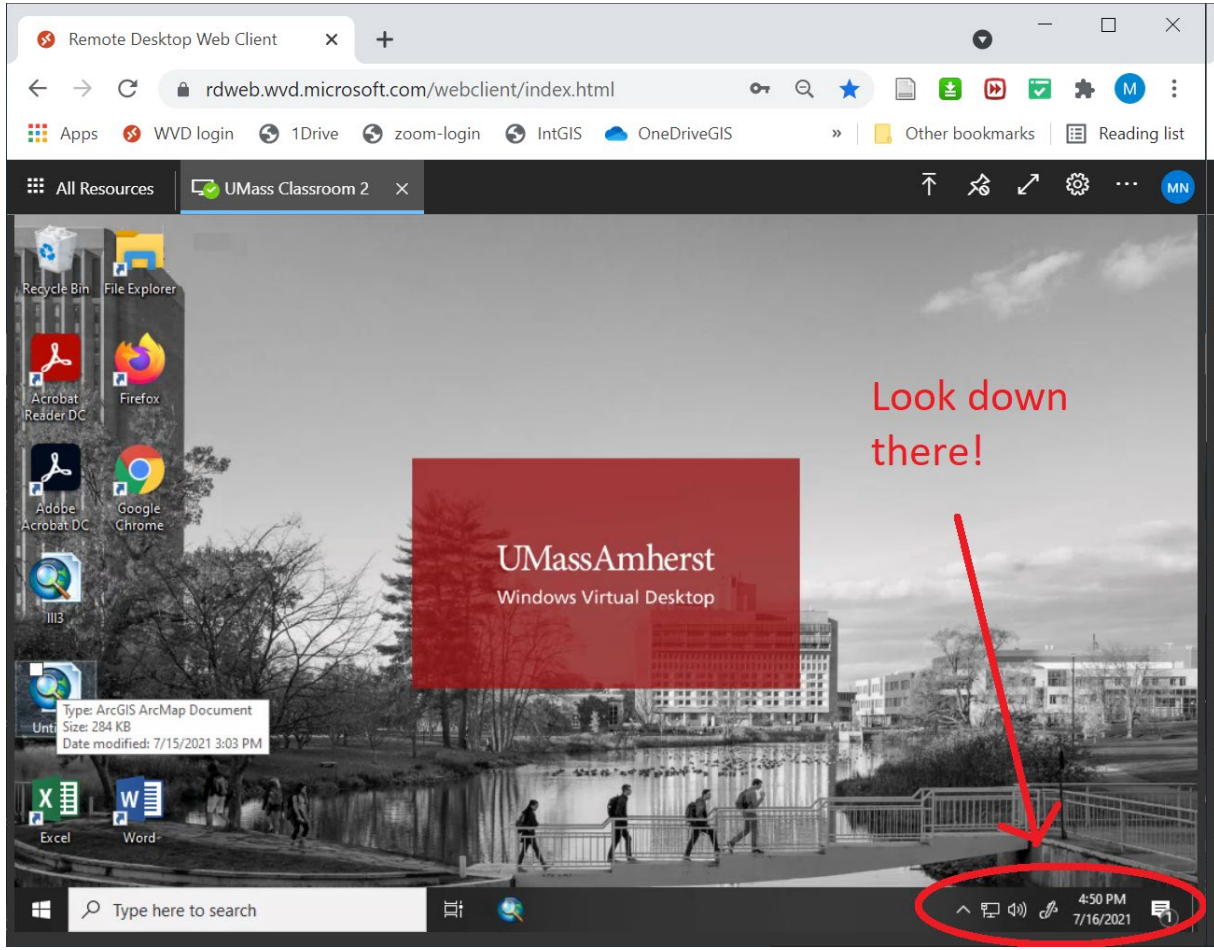
Overview

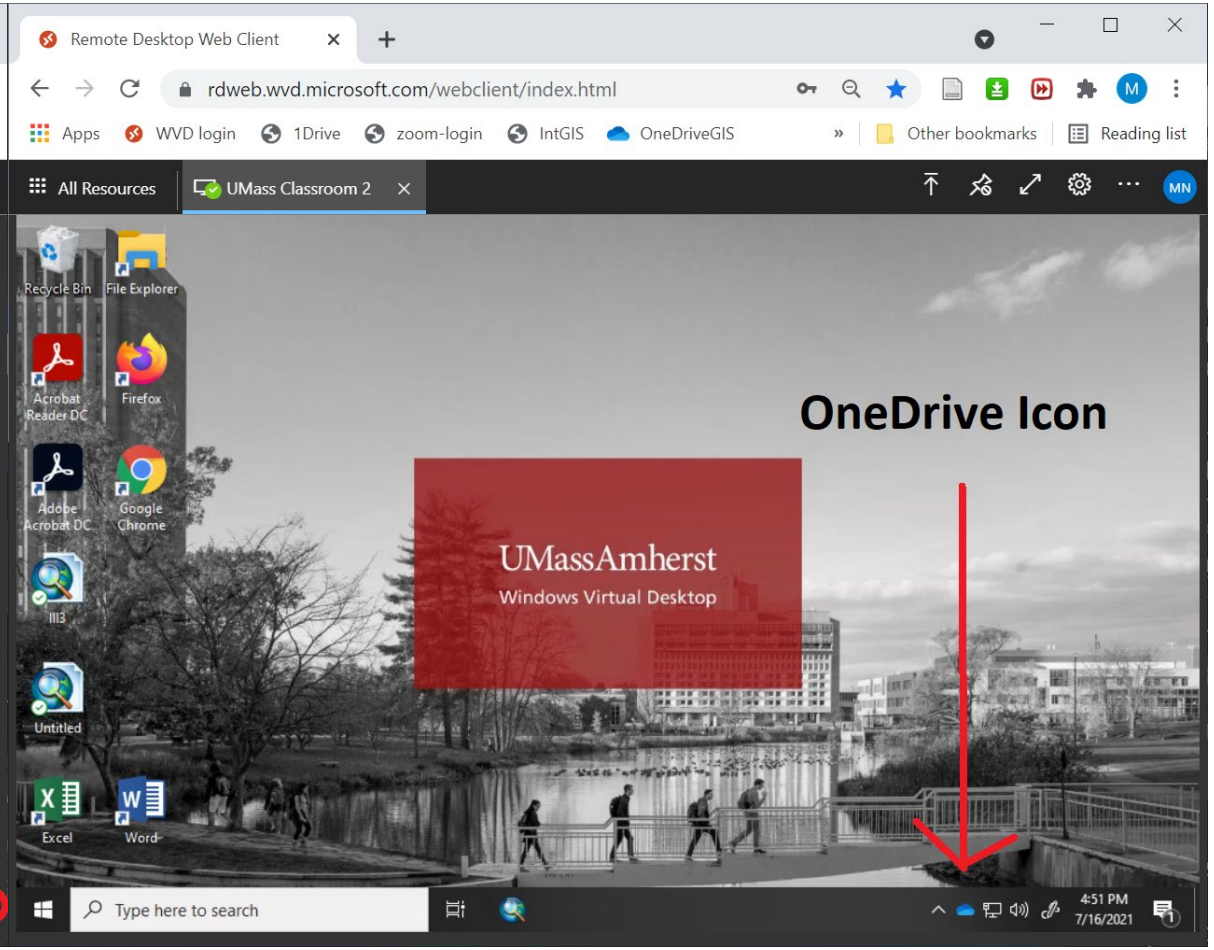
- Projections: Recap
- Practical Exam Info

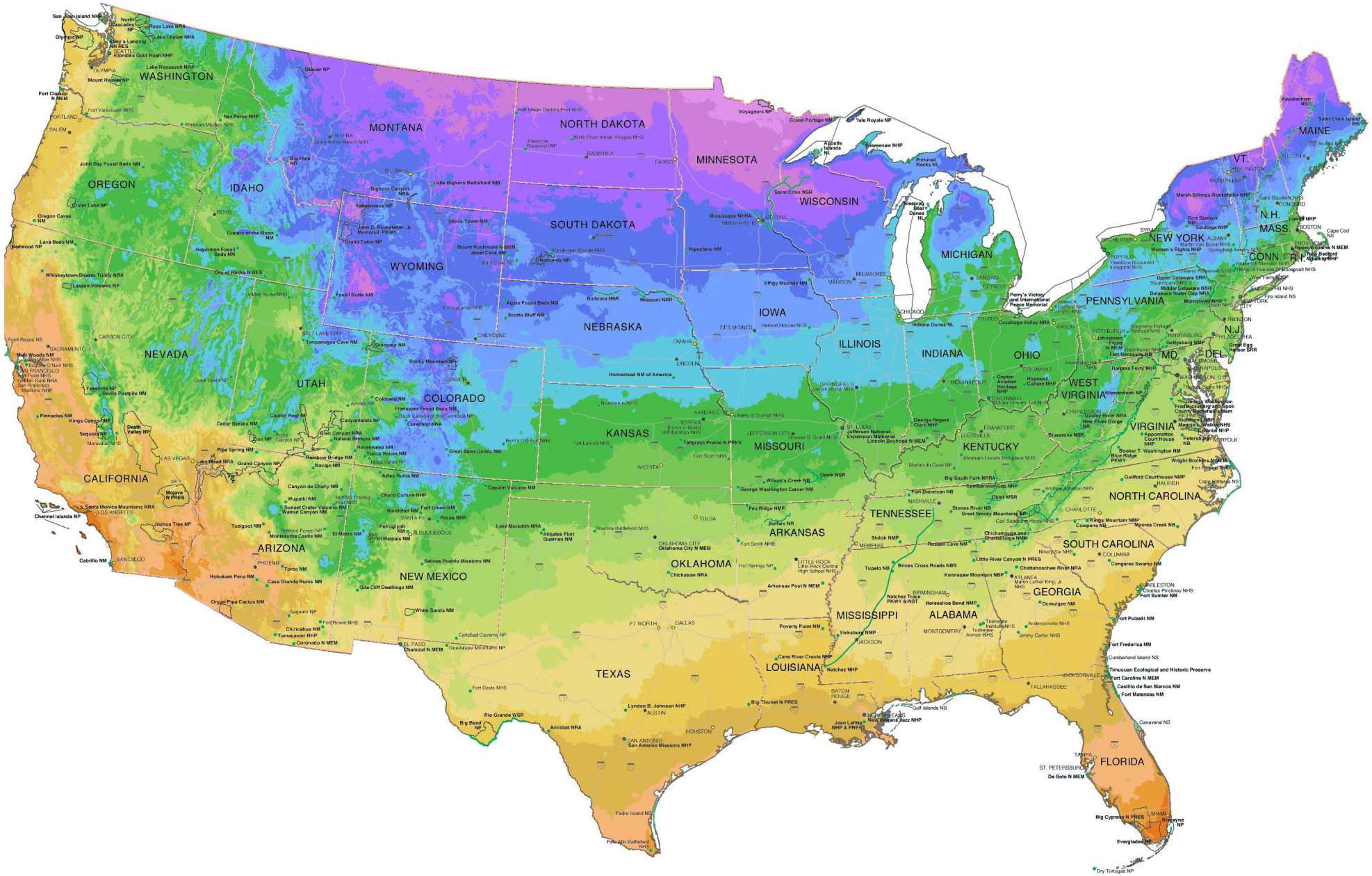
Once upon a OneDrive

- Make sure you have file sync turned on when you use WVD!
  - You probably do, but it never hurts to check.
- Check the system tray for OneDrive status

Once upon a OneDrive






WASHINGTON
OREGON
IDAHO
MONTANA
NORTH DAKOTA
MINNESOTA
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WYOMING
NEBRASKA
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MICHIGAN
ILLINOIS
INDIANA
OHIO
NEVADA
UTAH
COLORADO
KANSAS
MISSOURI
KENTUCKY
WEST VIRGINIA
PENNSYLVANIA
NEW YORK
MAINE
VT.
N.H.
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CONN.
R.I.
N.J.
DEL.
MD.
VIRGINIA
NORTH CAROLINA
SOUTH CAROLINA
GEORGIA
FLORIDA
ALABAMA
MISSISSIPPI
TENNESSEE
ARKANSAS
LOUISIANA
OKLAHOMA
TEXAS
NEW MEXICO
ARIZONA
CALIFORNIA

Next week is spring break!

- Rest, regroup, and relax as much as possible, and think about your GIS questions!
- Week 6 will be midterm concept review
- Week 7 will be midterm.

Midterm Info

About the Midterm

- The midterm will automatically open on Friday June 16th at 12:01 AM, and close on Friday June 23rd at 11:59PM.
- This gives you about 8 days to complete it.

About the Midterm

- The Practical is an independent test of your GIS abilities on concepts through lab 5.
- It is not a closed book exam.

About the Midterm

- You **can** use:
  - Your notes and old labs
  - Google/Internet/ESRI Help
  - Discussion with others in the class in public rooms during the lab period

About the Midterm

- You **can't** use:
  - Myself or the TAs
    - We can answer questions about the wording of questions, but not concepts or contents.
  - Private communication with others in the class

Before you Attempt the Midterm

- You should have completed labs 1 – 5.
  - If you aren’t comfortable with this material, you won’t do well on the midterm!
  - Be in touch right away if you’re falling behind, or have timing concerns.

Before you Attempt the Midterm

- So… if you're struggling with completing things, reach out ASAP.
- If you communicate , we can help you!
  - If we don't hear from you, there's not much we can do!

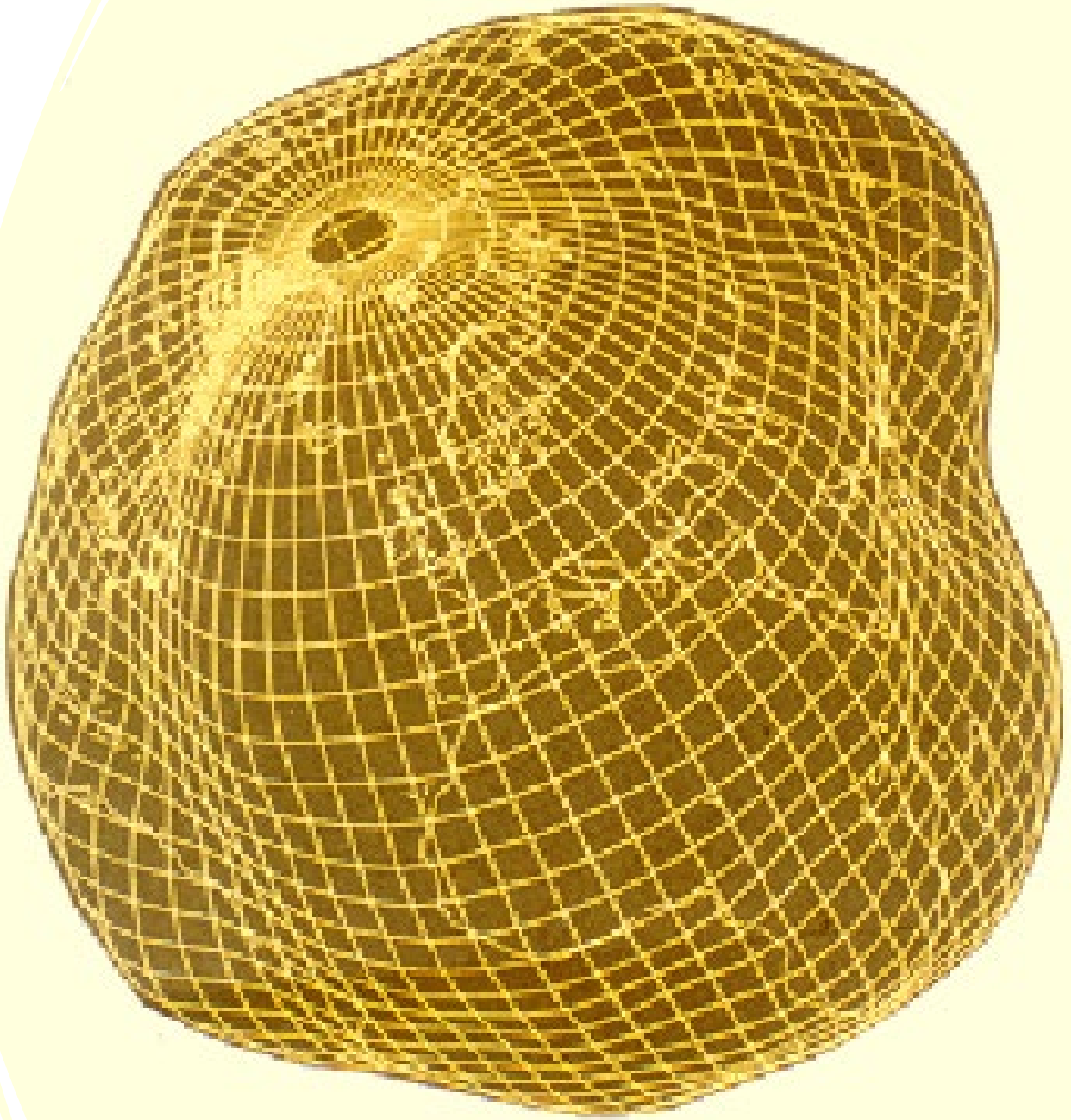
Next lecture is all about the midterm!

- Cue up your questions!

Modeling The Earth's Shape

A very brief review

What is Earth's shape?

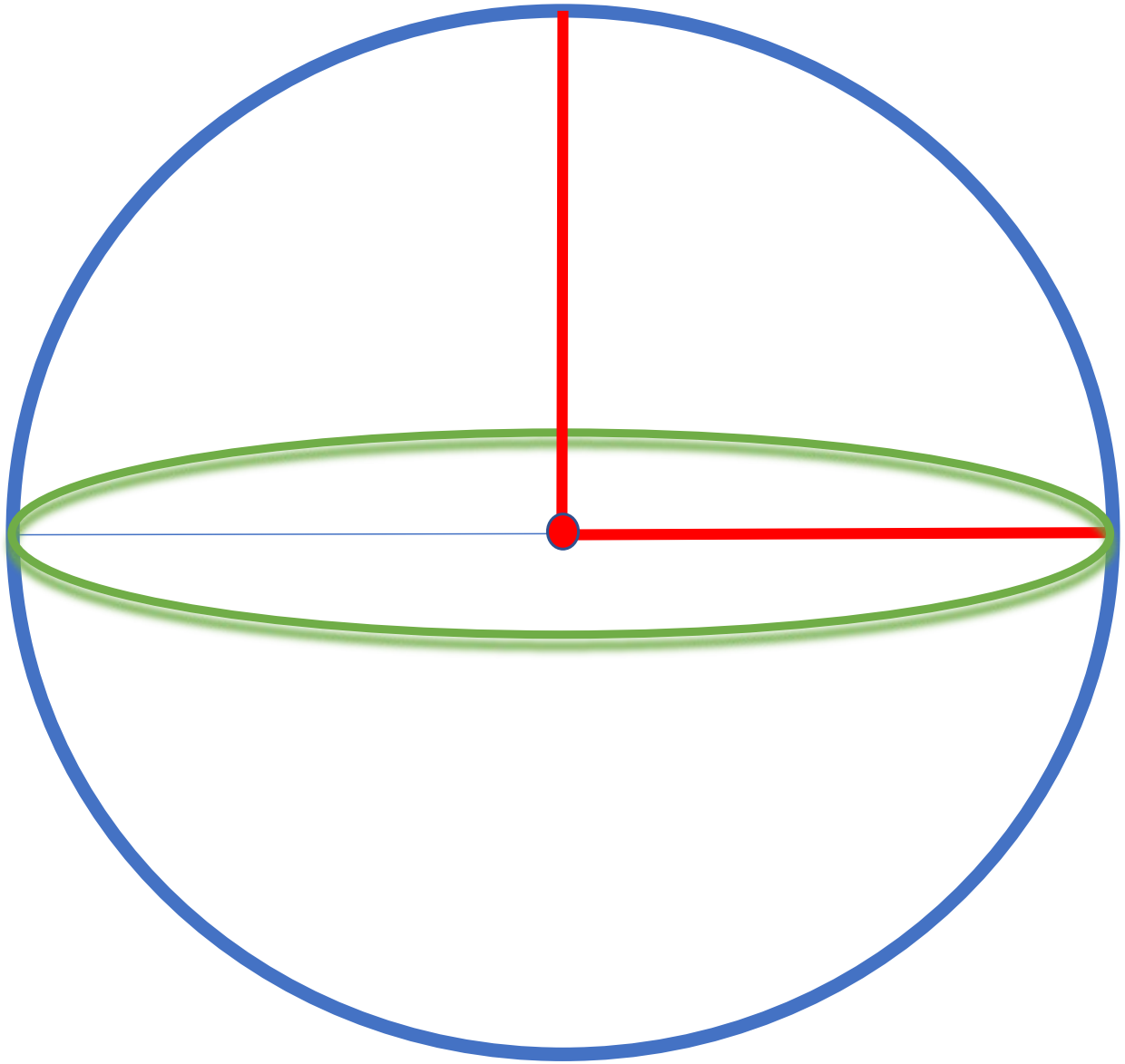


From Lumpy Space Potato to Projected Coordinates

- Abstraction: ellipsoid model
- Parameterizing the ellipsoid
- Geographic Coordinate System (GCS)
- Anchoring the ellipsoid: the datum
- From 3D to 2D: projecting

Model Thinking: A useful simplification of the earth's shape?

- Flat*?
- Sphere?
- Ellipsoid?
- Lumpy Space Potato?
- Geoid?



* The earth is not flat.

Lumpy Space Potato

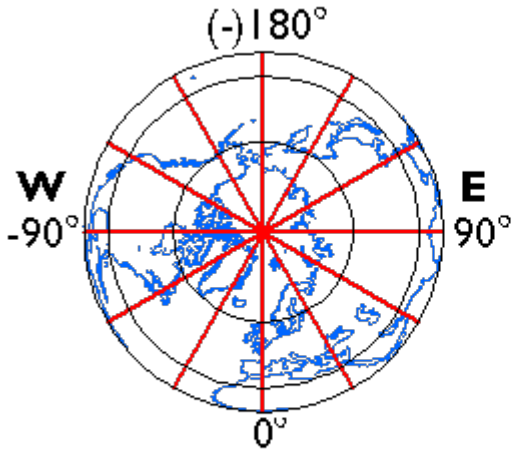
Geoid

Datum

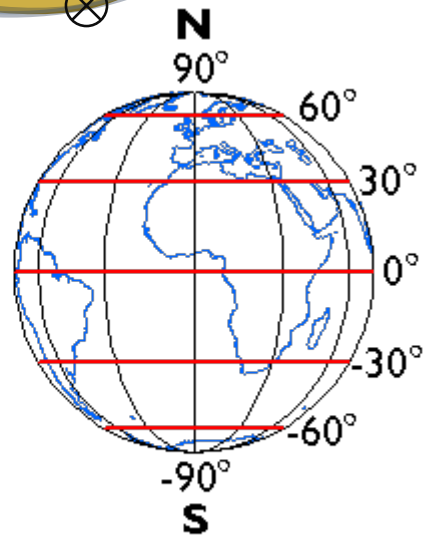
1. Ellipsoid
2. Anchor Points

Spherical Coordinates

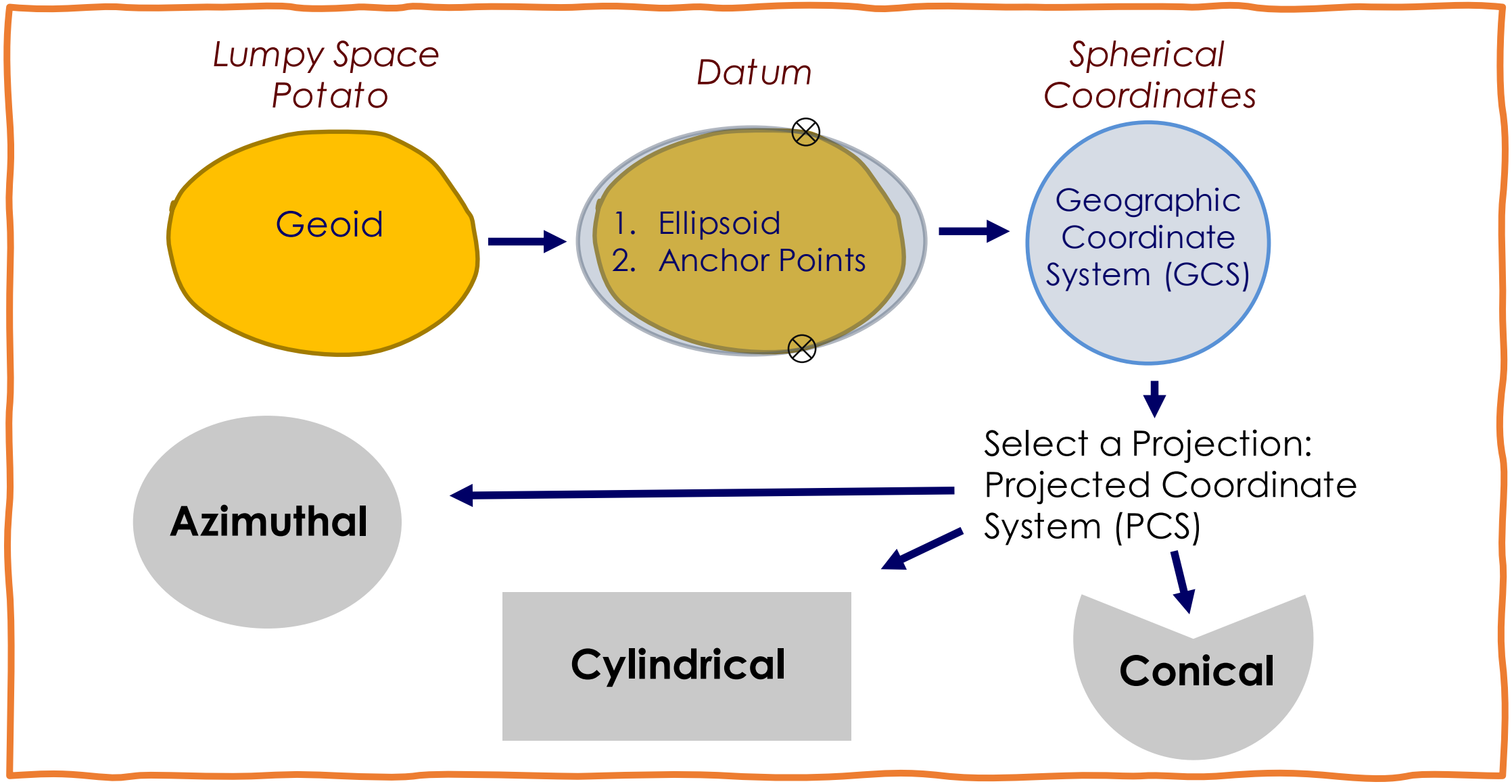
Geographic Coordinate System (GCS)



Longitude



Latitude


Lumpy Space Potato
Geoid
Datum
1. Ellipsoid
2. Anchor Points
Spherical Coordinates
Geographic Coordinate System (GCS)
Select a Projection: Projected Coordinate System (PCS)
Azimuthal
Cylindrical
Conical

A Tale of Two Coordinate Systems

Geographic Coordinate System (GCS)

- Spherical coordinates: degrees
  - Problematic because it does not directly relate to physical distance
  - A GIS may not be able to properly calculate distance or area.
  - Some geoprocessing operations require a PCS
- **Associated with a particular datum**

Projected Coordinate System (PCS)

- Planar coordinates: usually meters, feet, km, or miles
  - Useful for measuring distance or area.
- Derived from a GCS by a mathematical function
- **Associated with a particular datum**

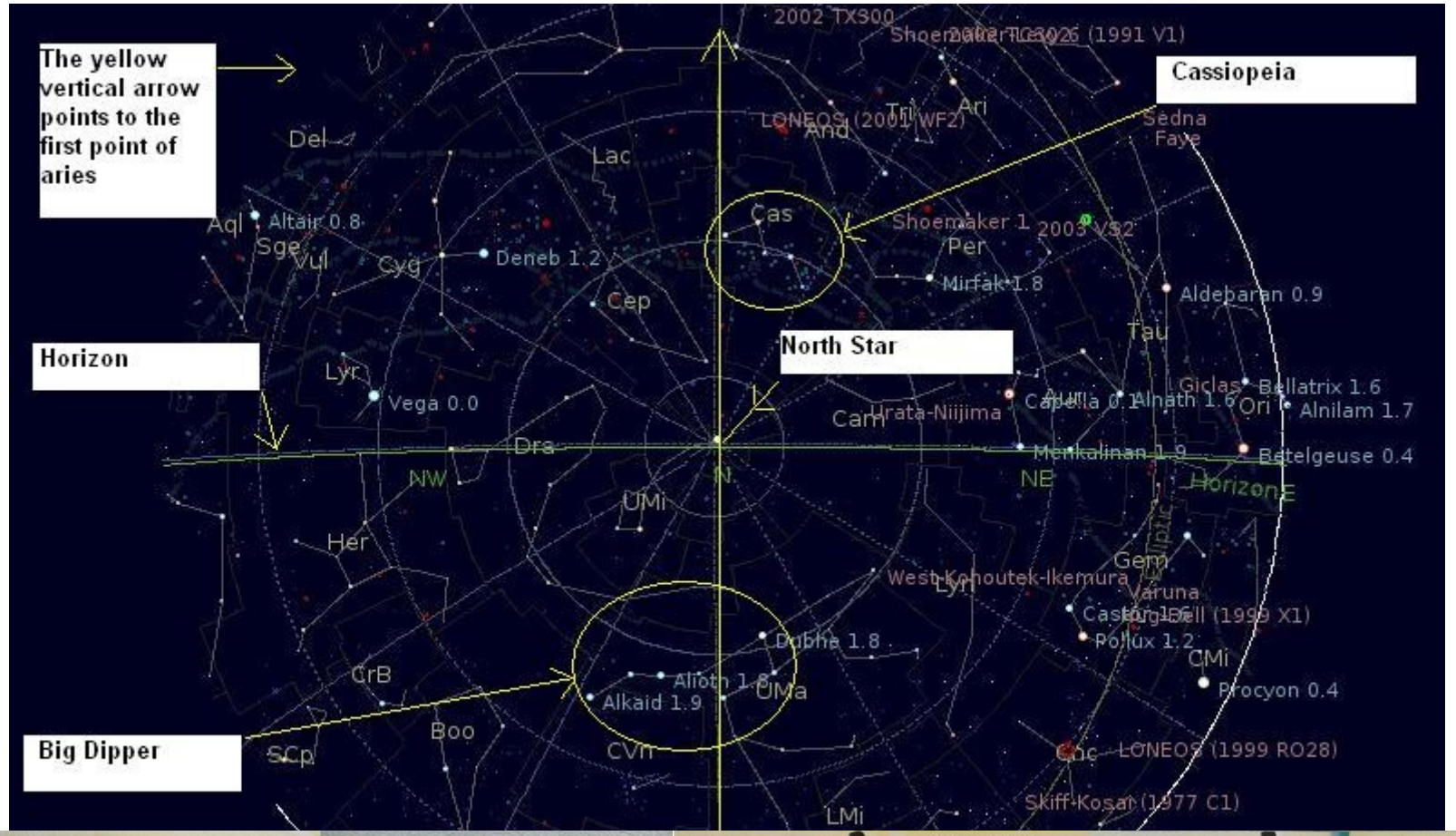
Time for a stretch break

And Zoom Poll!

How should we specify location?

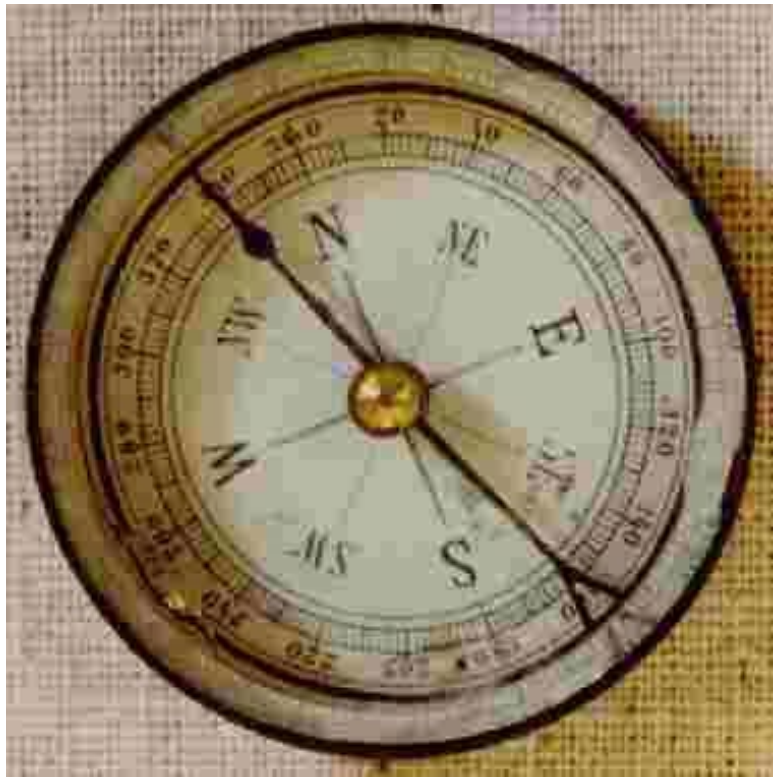
- A map?
- Direction and distance?
- Relative location?
- Absolute location?

Old-school: Celestial Navigation



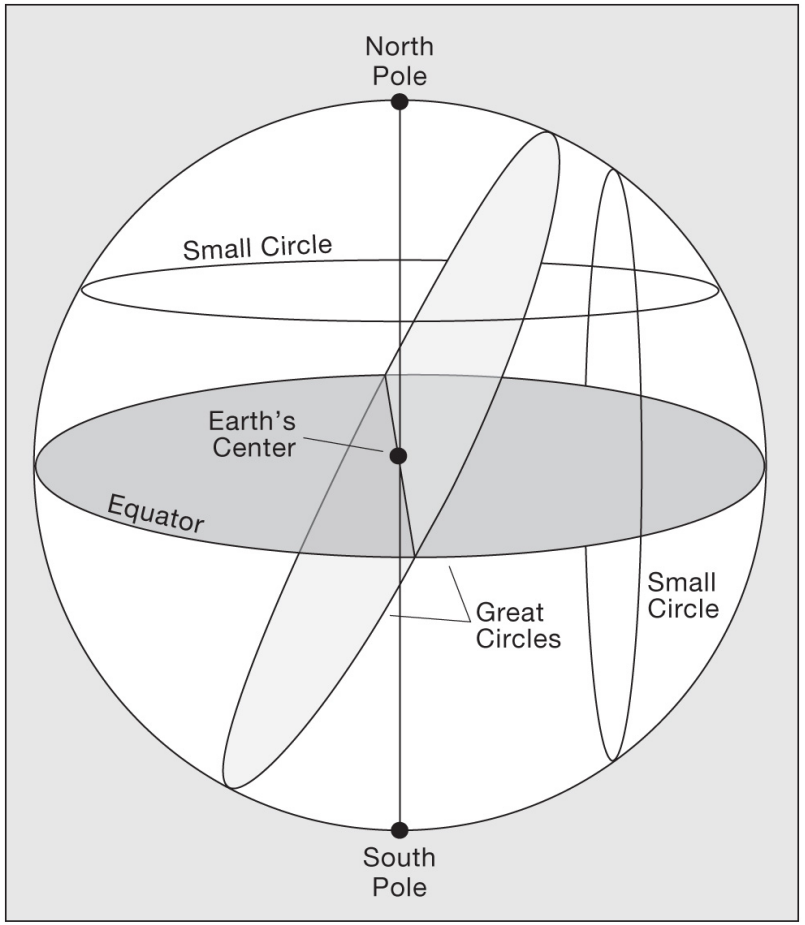
Old-school: Dead Reckoning

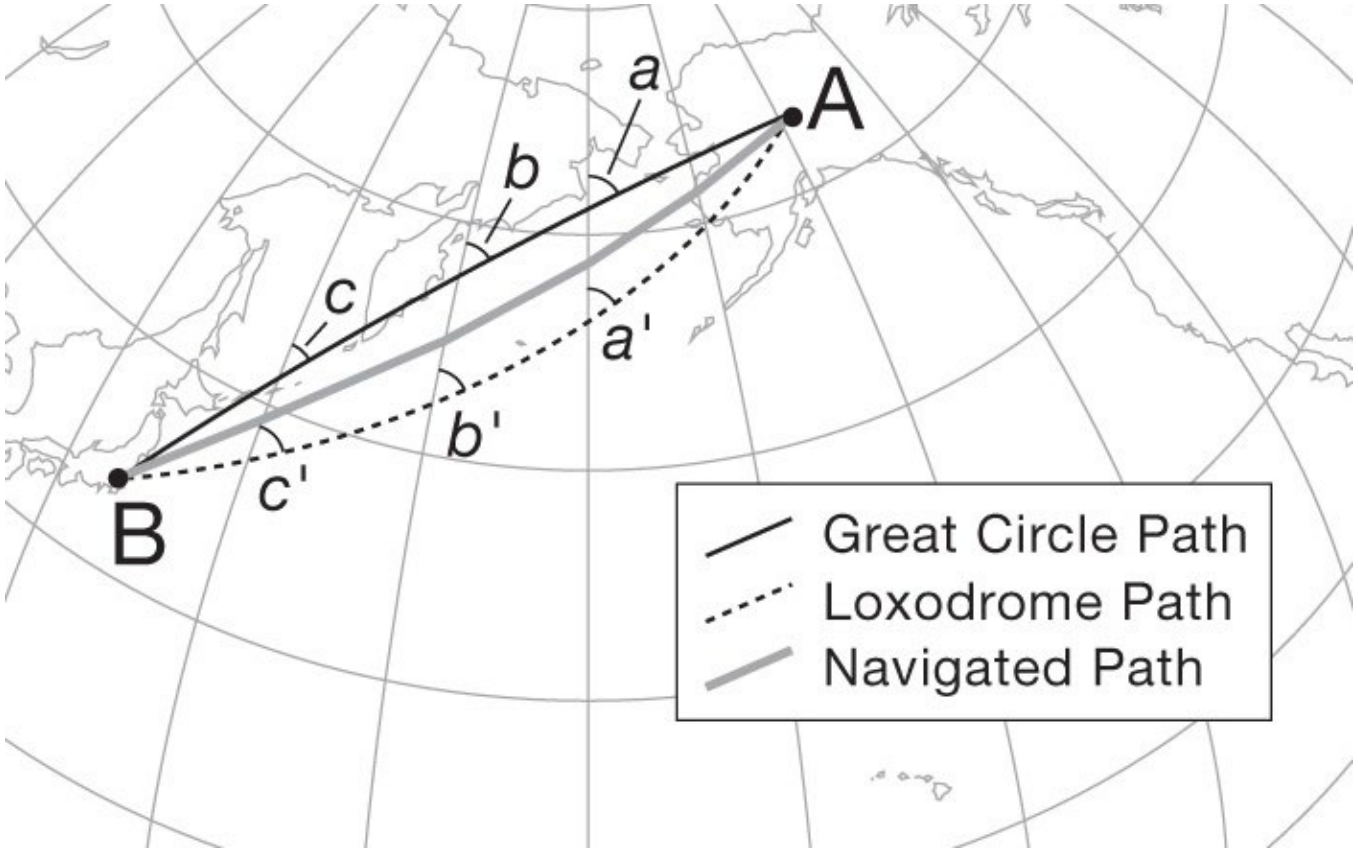
If you know where you are to begin with, you can use only **direction** and **distance** (plus a chart/map) to figure out where you end up.



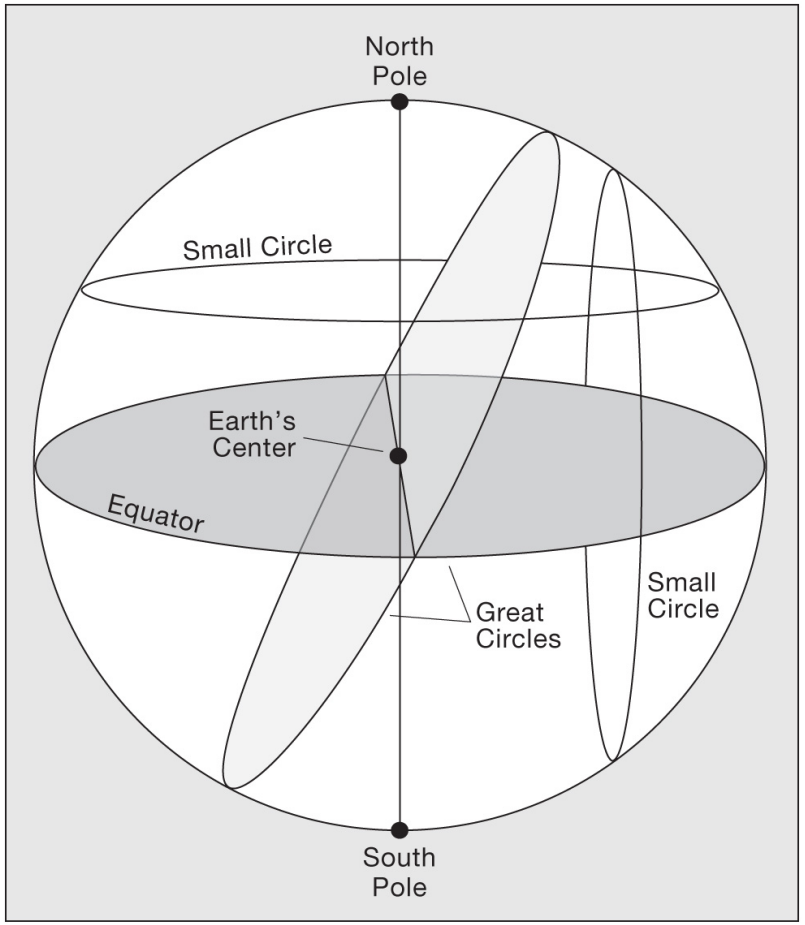
Old-school: Dead Reckoning

If you know where you are to begin with, you can use **direction** and **distance** to figure out where you end up. Remember rhumb lines and great circles?





Old-school: Dead Reckoning



If you know where you are to begin with, you can use **direction** and **distance** to figure out where you end up. Remember rhumb lines and great circles?

A rhumb line (loxodrome) intersects all lines of longitude (meridians) at the same angle.

- You never have to change your compass bearing!
- May be easier to use than a circle path
- Longer than a circle path.

A great (or small) circle path may intersect meridians at different angles.

- Need to constantly update compass bearing

Relative Location

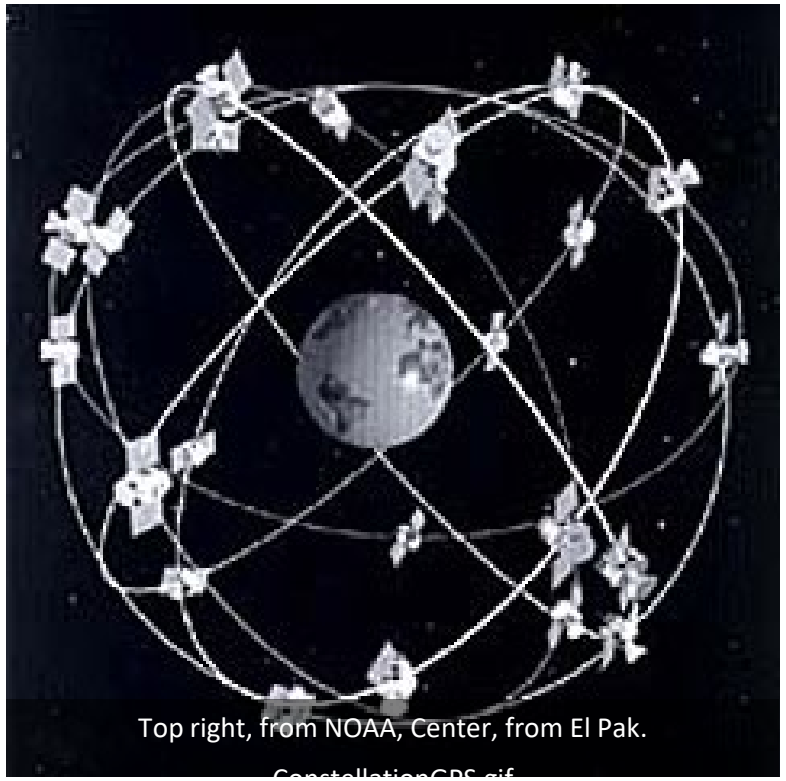
- Relative location positions you in relation to another object.
- In this example, we can say that Hawaii is south of Alaska.

Absolute Location

- Absolute locations references some standardized grid or location system, like latitude and longitude along with a datum, like the World Geodetic System.

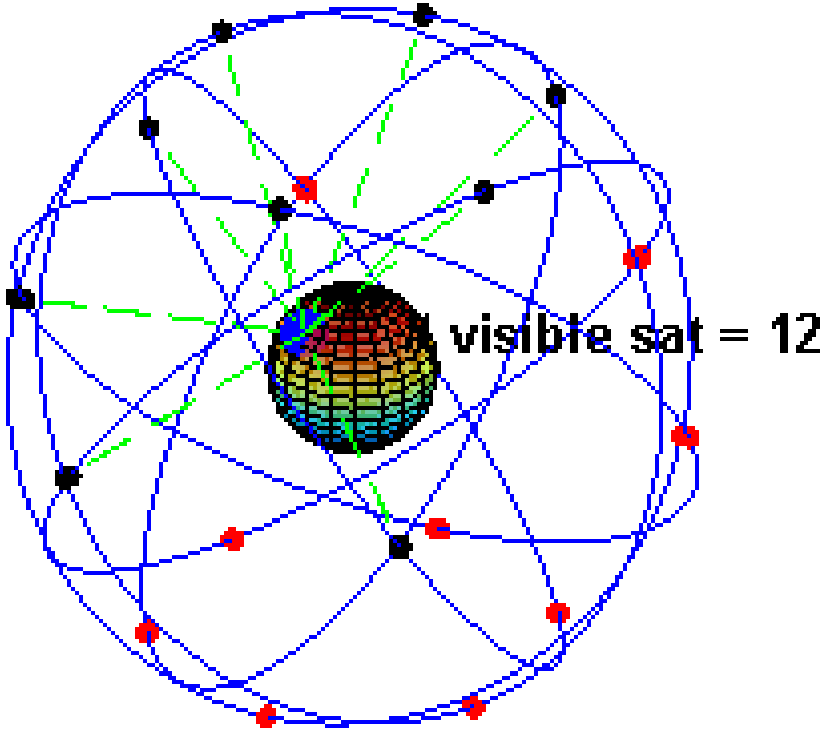
GPS

The global positioning system allows us to know our absolute location, with reasonable accuracy, anywhere on the planet.



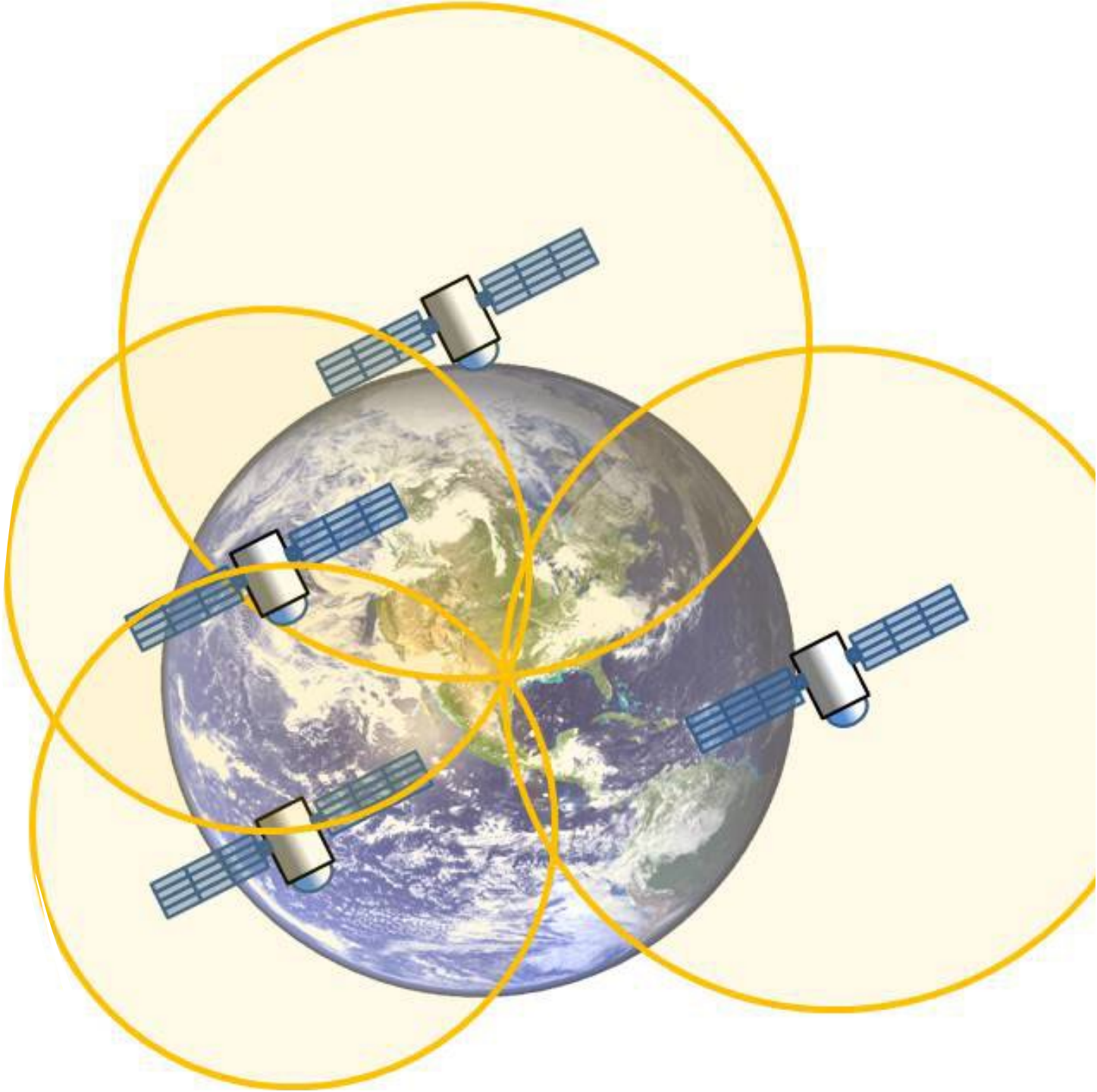
Top right, from NOAA, Center, from El Pak.

ConstellationGPS.gif



GPS

- Consider imaginary spheres centered on each GPS satellite.
- GPS receiver uses time and speed (of light) to calculate distance to satellite.
- But where are the satellites?

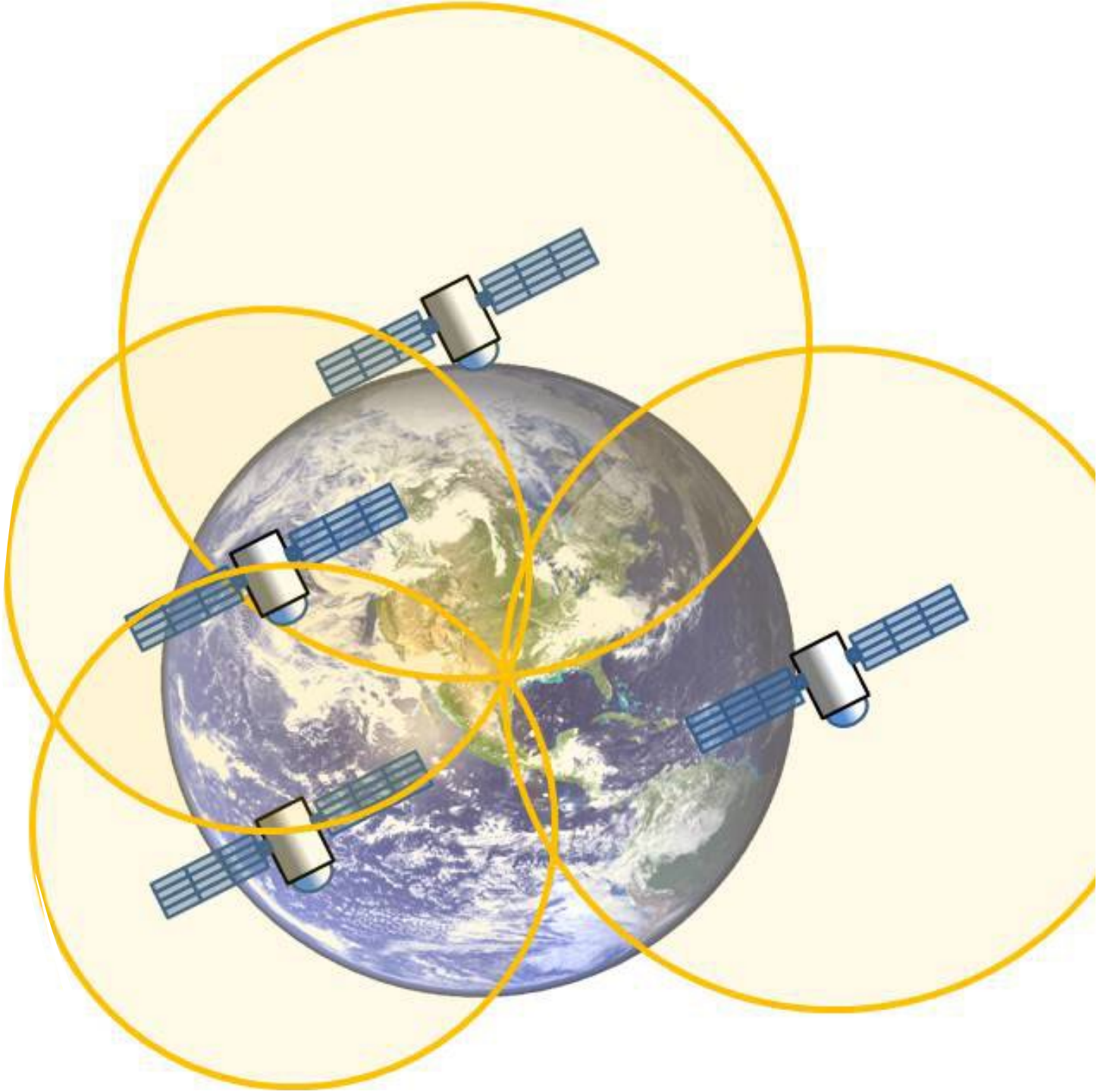


3dtriangulation.jpg Adapted from Quiring 2012, pp. 2

GPS Components

A GPS has 2 main components:

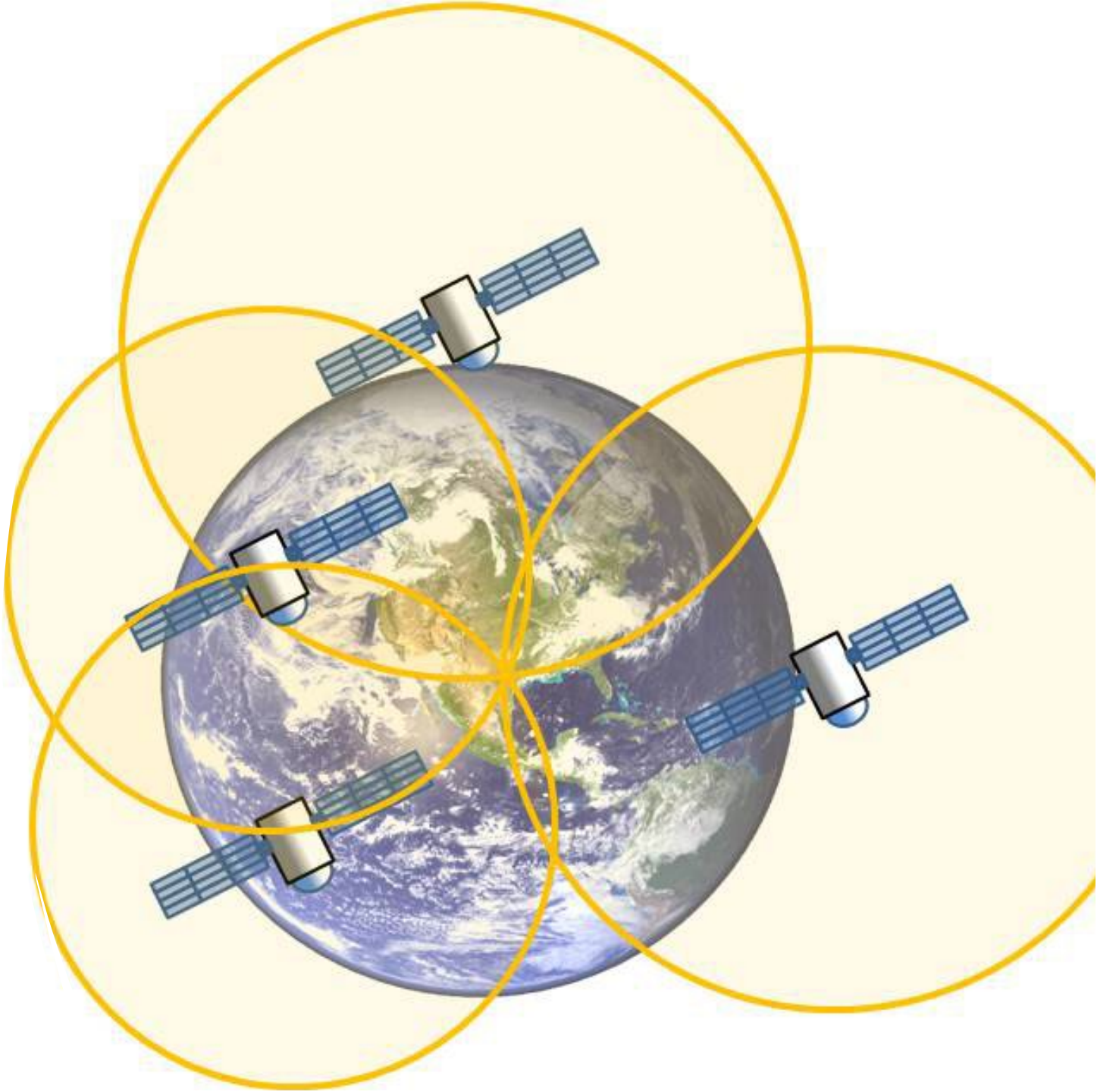
- Almanac: locations of satellites
- Ephemeris: time difference



3dtriangulation.jpg Adapted from Quiring 2012, pp. 2

GPS: Almanac

- But where are the satellites?
- You need to know the locations of at least 4 satellites in the sky to accurately figure out where you are!
- There are usually 6 visible at all times.



3dtriangulation.jpg Adapted from Quiring 2012, pp. 2

GPS

- All electromagnetic radiation (radio waves to x-rays) travel at speed of light (300,000,000 meters/second).

- GPS systems use radio waves to transmit information.

http://en.wikipedia.org/wiki/File:GPS_Satellite_NASA_art-iif.jpg

GPS

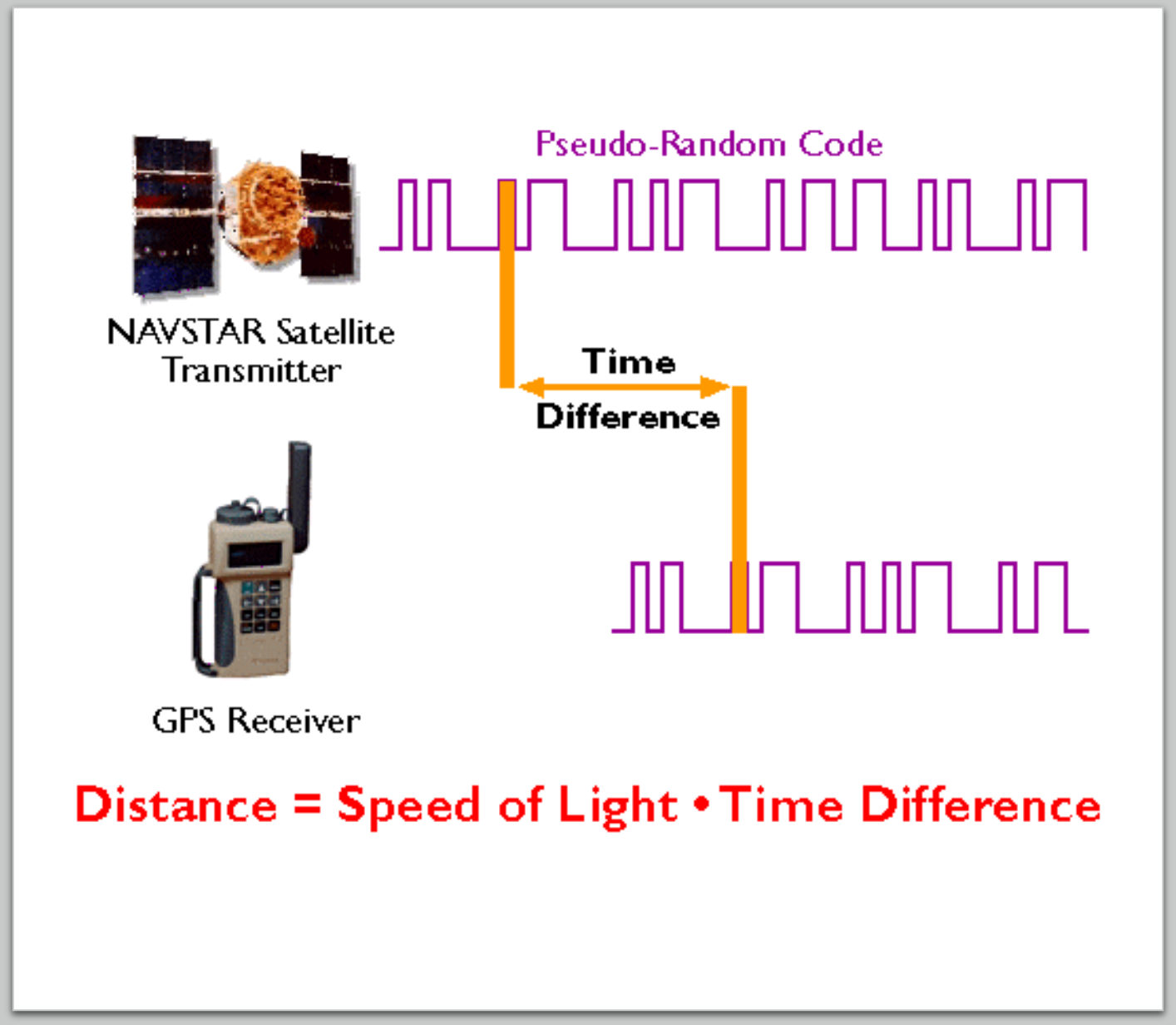
Einstein's relativity tells us:

- Speed of light is constant for every observer
- We perceive that time happens 'faster' on the satellites than on Earth's surface.
- We have to adjust ~ 38 microseconds per day

http://en.wikipedia.org/wiki/File:GPS_Satellite_NASA_art-iif.jpg

GPS

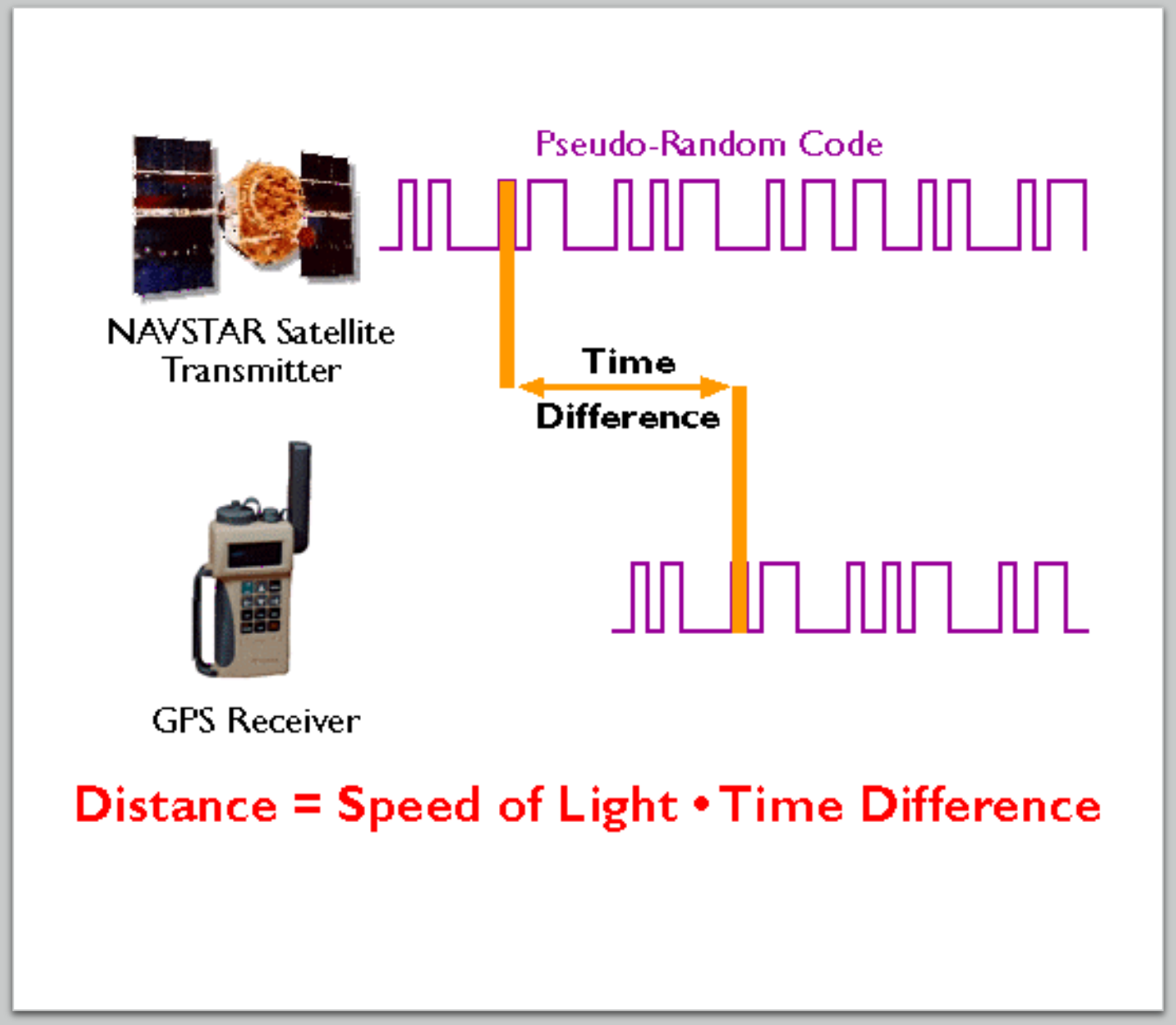
- Check out the garmin GPS info page [Link on GitHub].



https://www.e-education.psu.edu/natureofgeoinfo/book/export/html/1796, gps_time_difference.gif

GPS Ephemeris: Atomic clock time stamp

- Atomic clocks are extremely accurate.

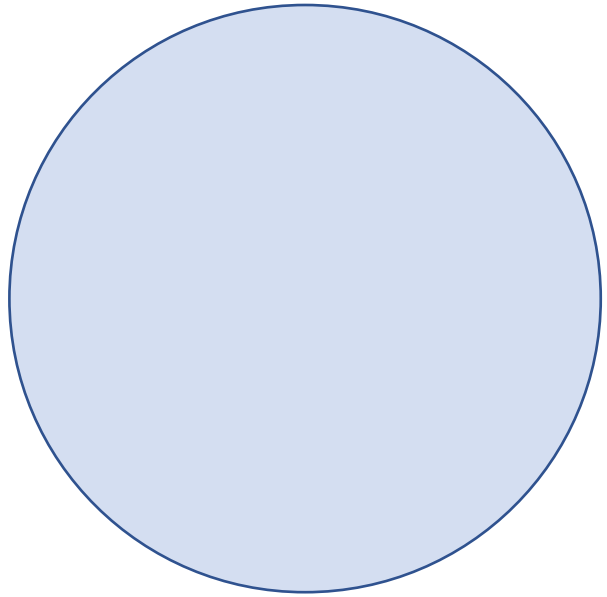


2D Triangulation

- You are 600 miles from Boise.

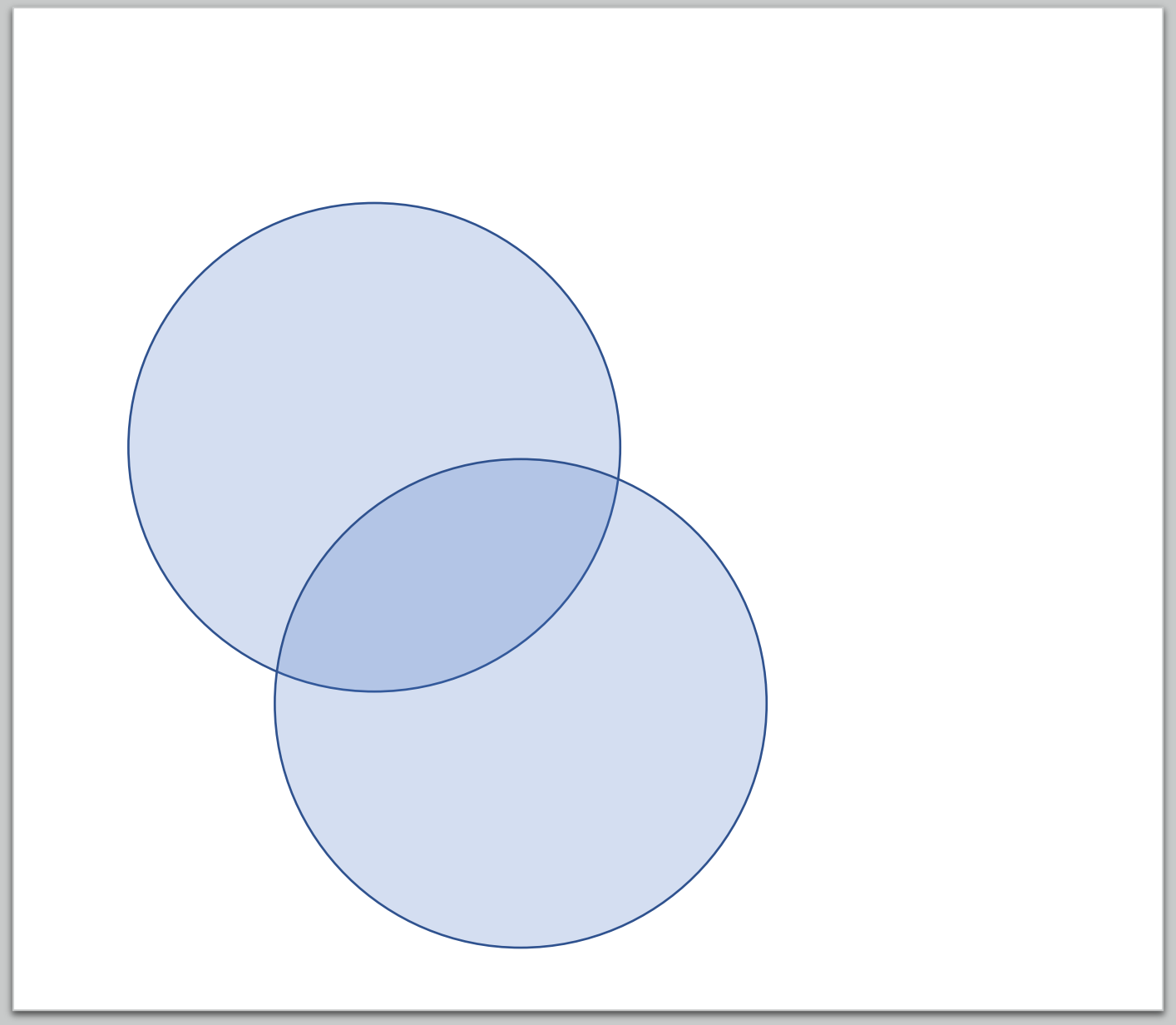
What does that tell you?

  - Not much: you could be anywhere on the edge of the circle



2D Triangulation

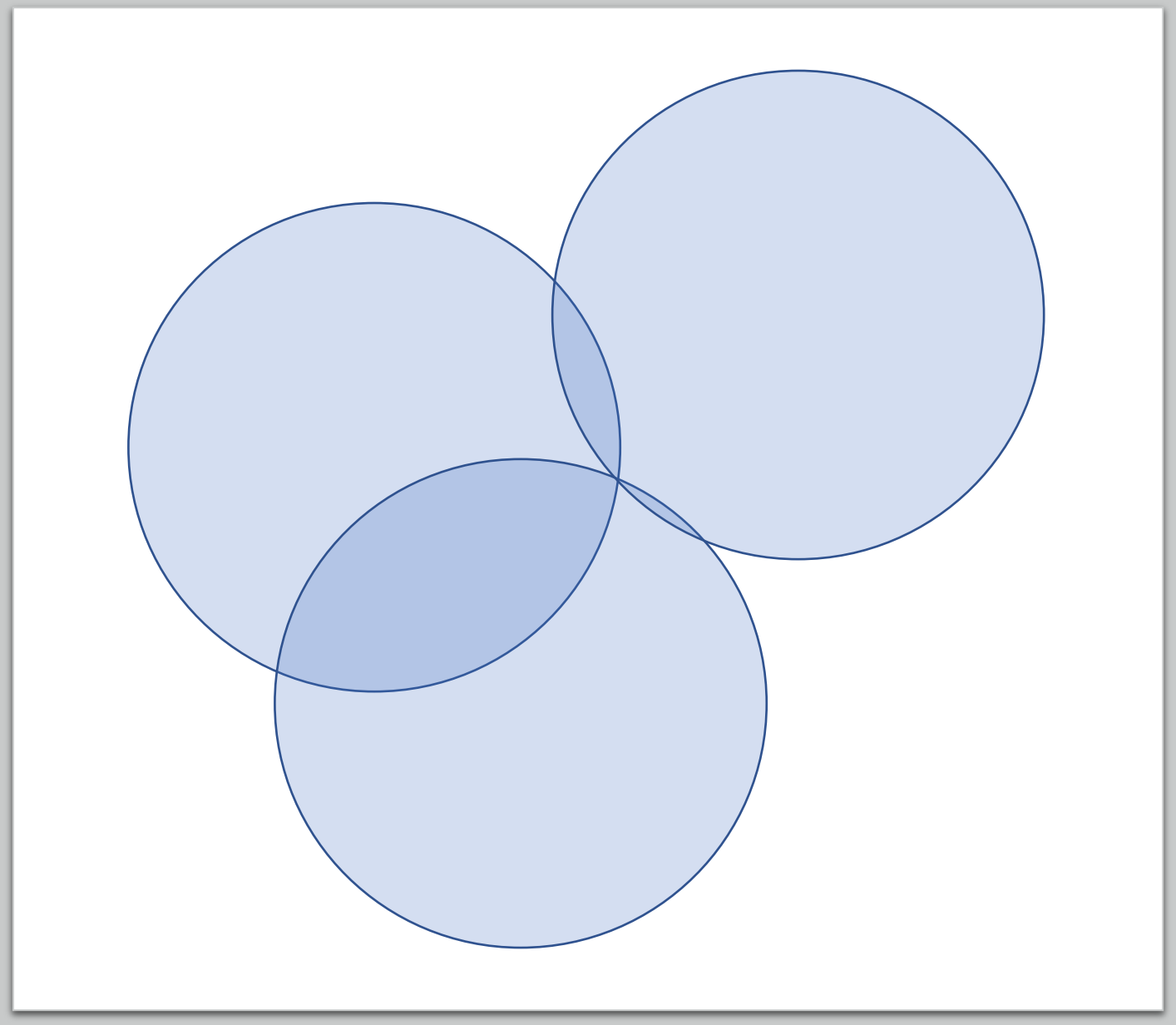
- You are 600 miles from Boise.
- You are also 600 miles from Tucson.
- Where are you now?
  - 2 possibilities: the points where the circles overlap!



2D Triangulation

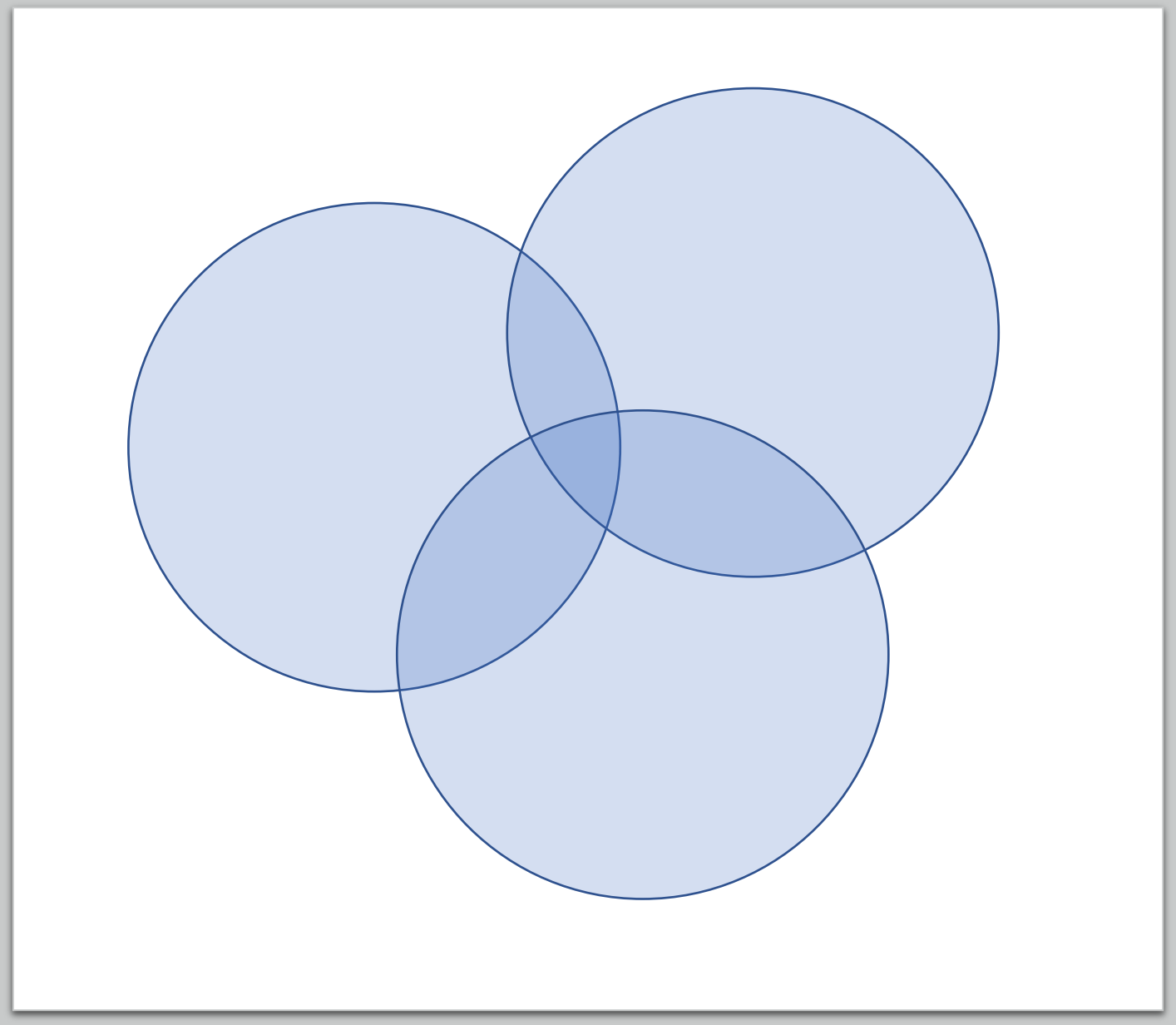
- You are 600 miles from Boise.
- You are also 600 miles from Tucson.
- You find out you're also 600 miles from Minneapolis.

- The third circle collapses the possibilities to one!
  - You're in Denver.



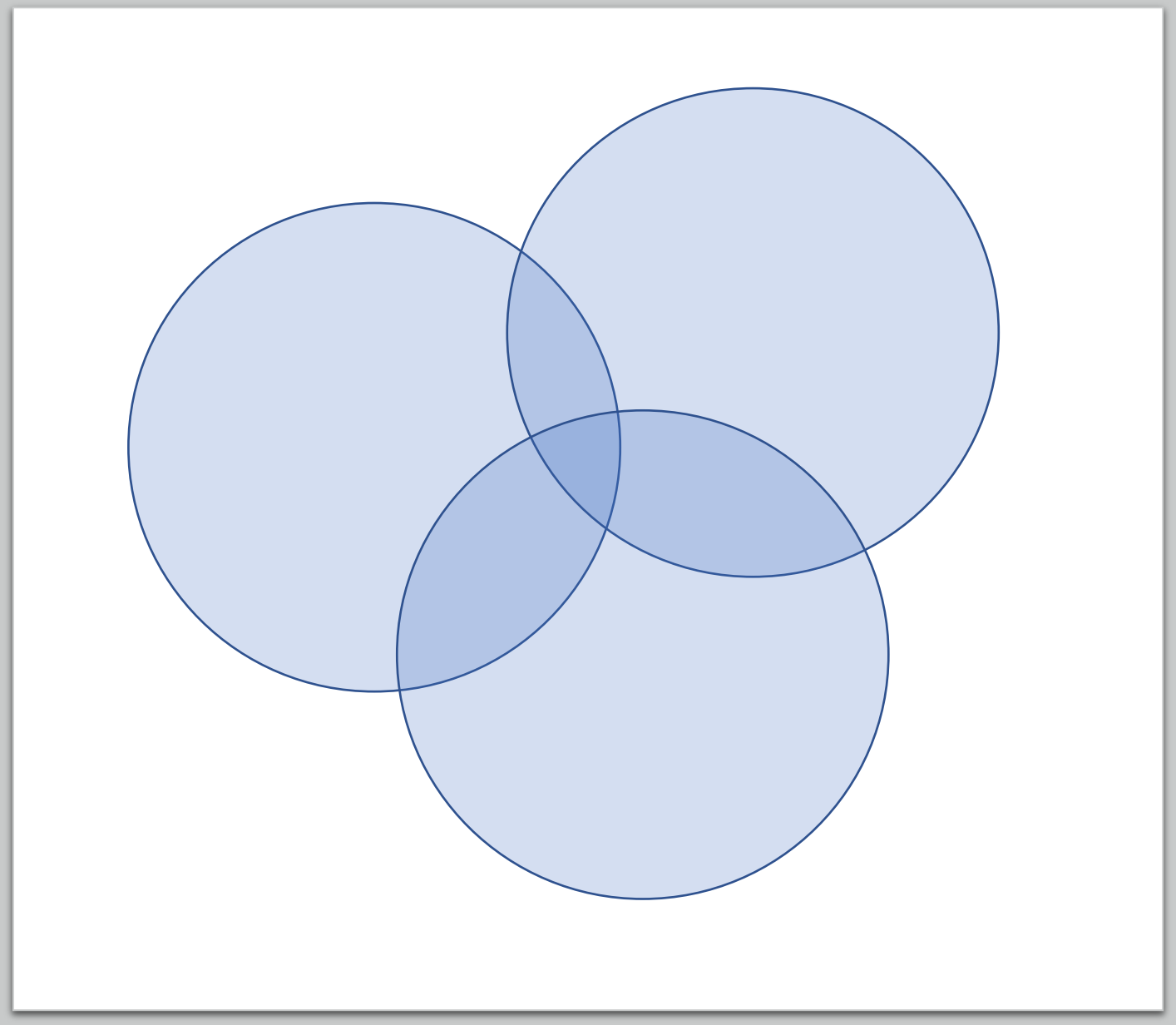
A Big Problem!

- Where am I now?



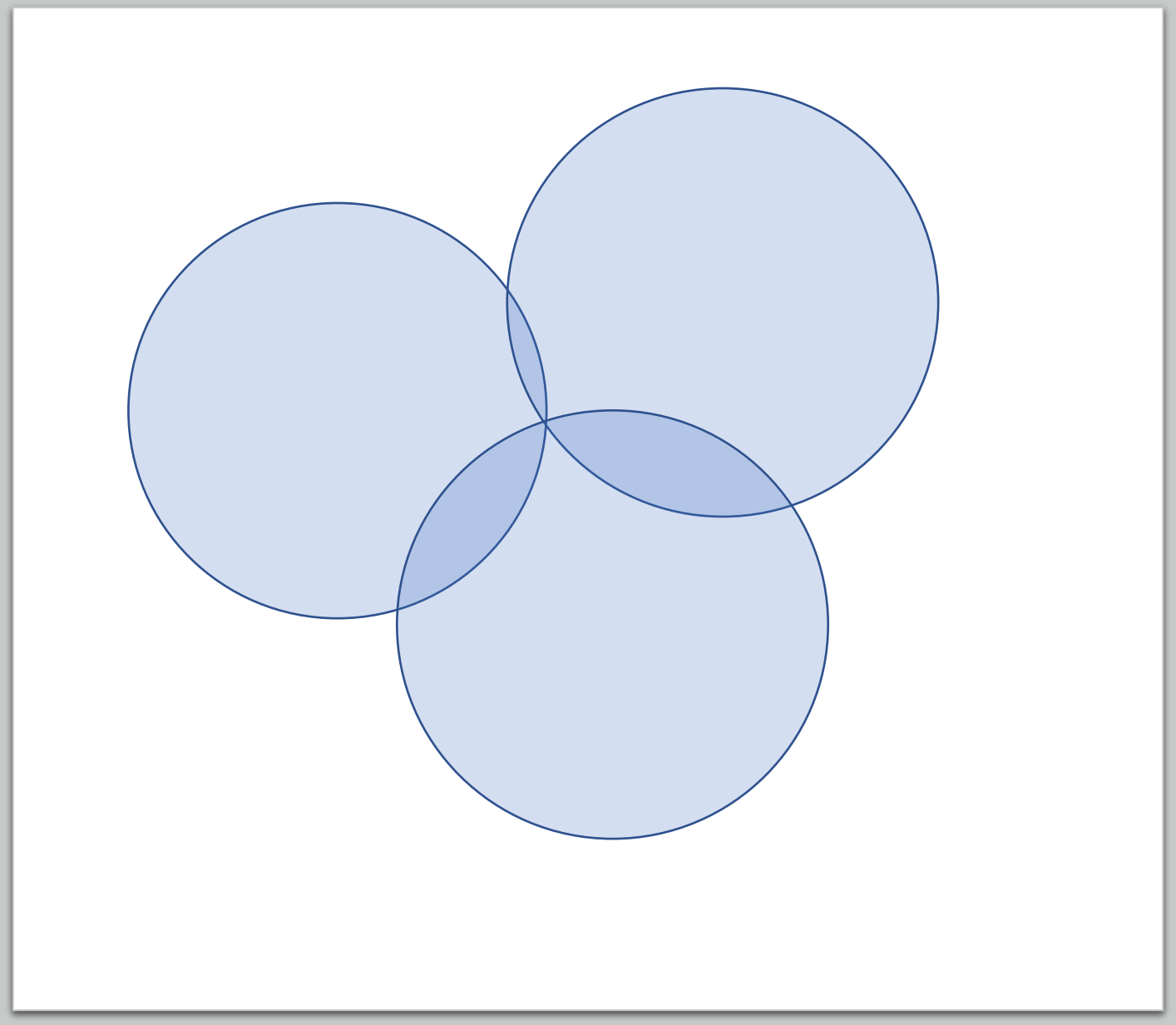
A Big Problem!

- The satellite clocks are extremely accurate
- The clock on your GPS unit is not!



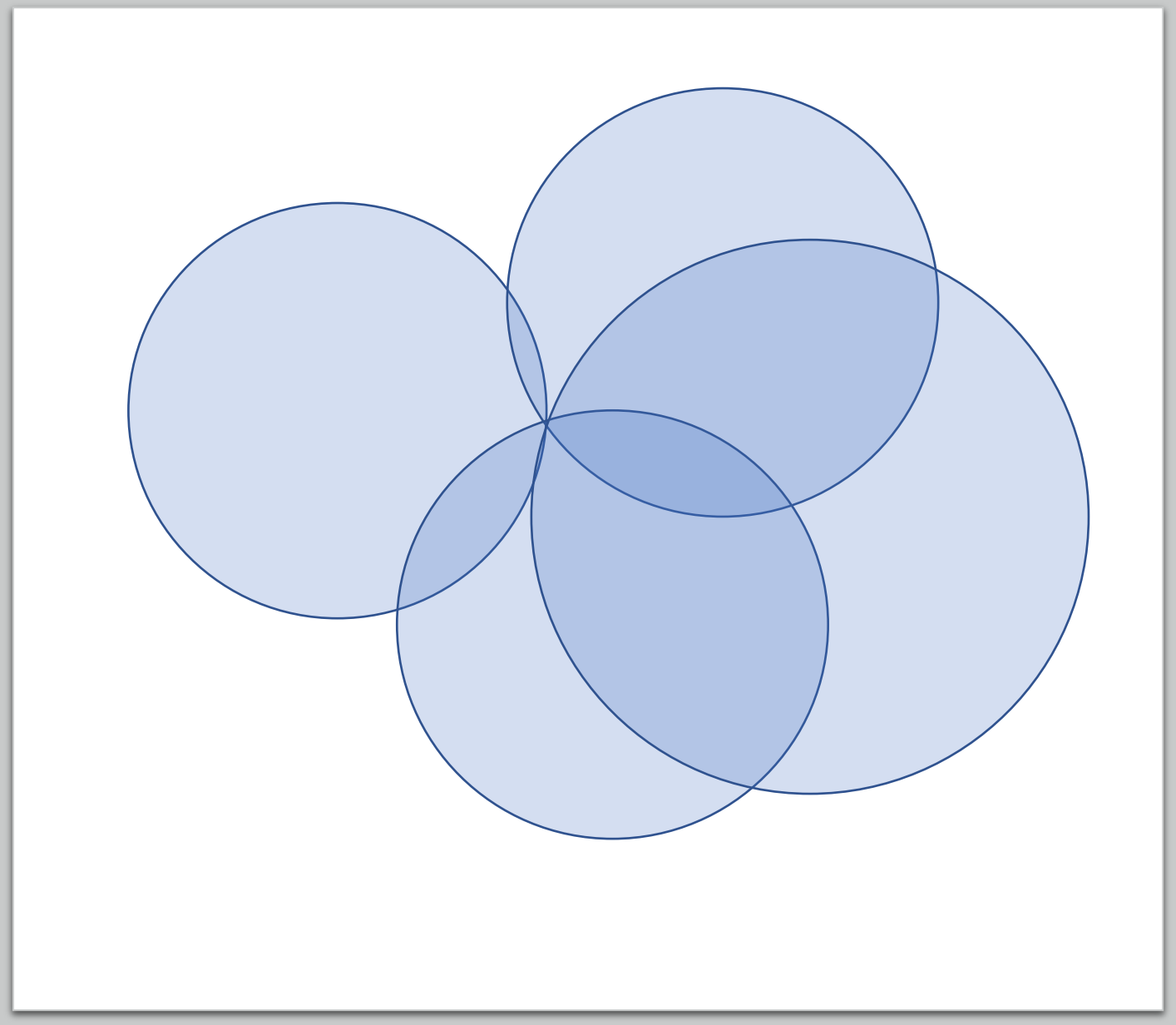
Speed of light to the rescue!

- The distance measurements by your unit are proportionally wrong.
- You can shrink your circles until they intersect.



Speed of light to the rescue!

- With GPS, the circles become spheres.
- With 4 satellites, you can correct for your unit's inaccurate clock



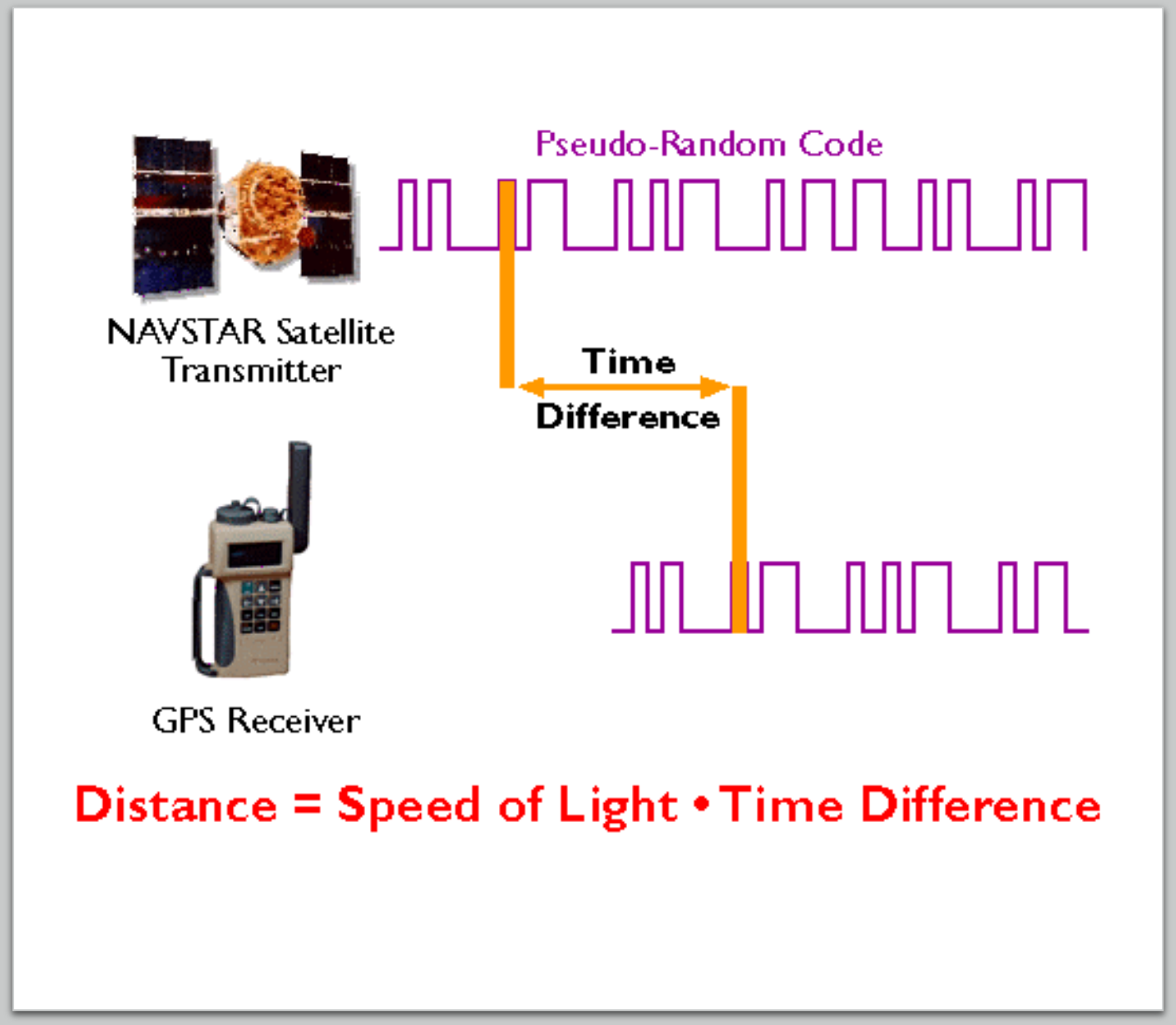
GPS: Almanac and Ephemeris

Almanac

- Positions of satellites in sky
- Provides your GPS with precise locations of satellites

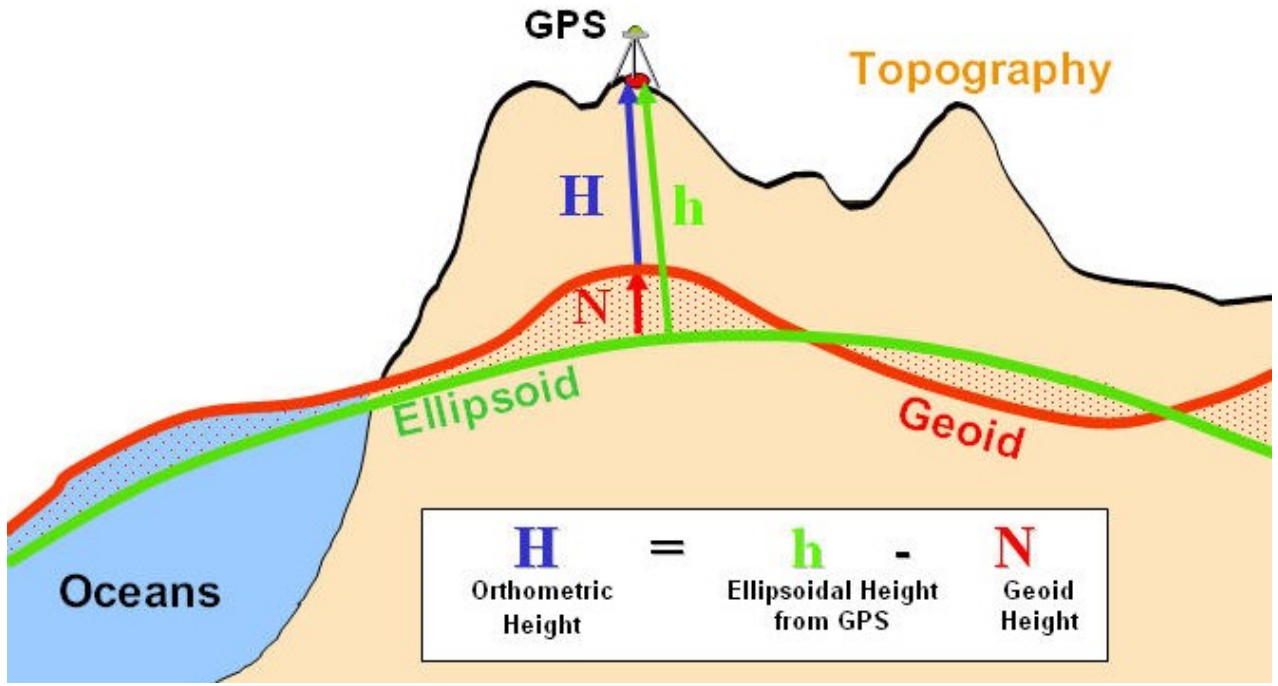
Ephemeris

- Satellites use atomic clocks
- Time stamp of when signal left the satellite
- Your unit compares the time the signal left to when it is received



GPS Issues

- Despite the general reliability of GPS, it is not a perfect system:
- Atmospheric and physical features distort and confuse the GPS signal, while the shape of the planet is also a difficulty.



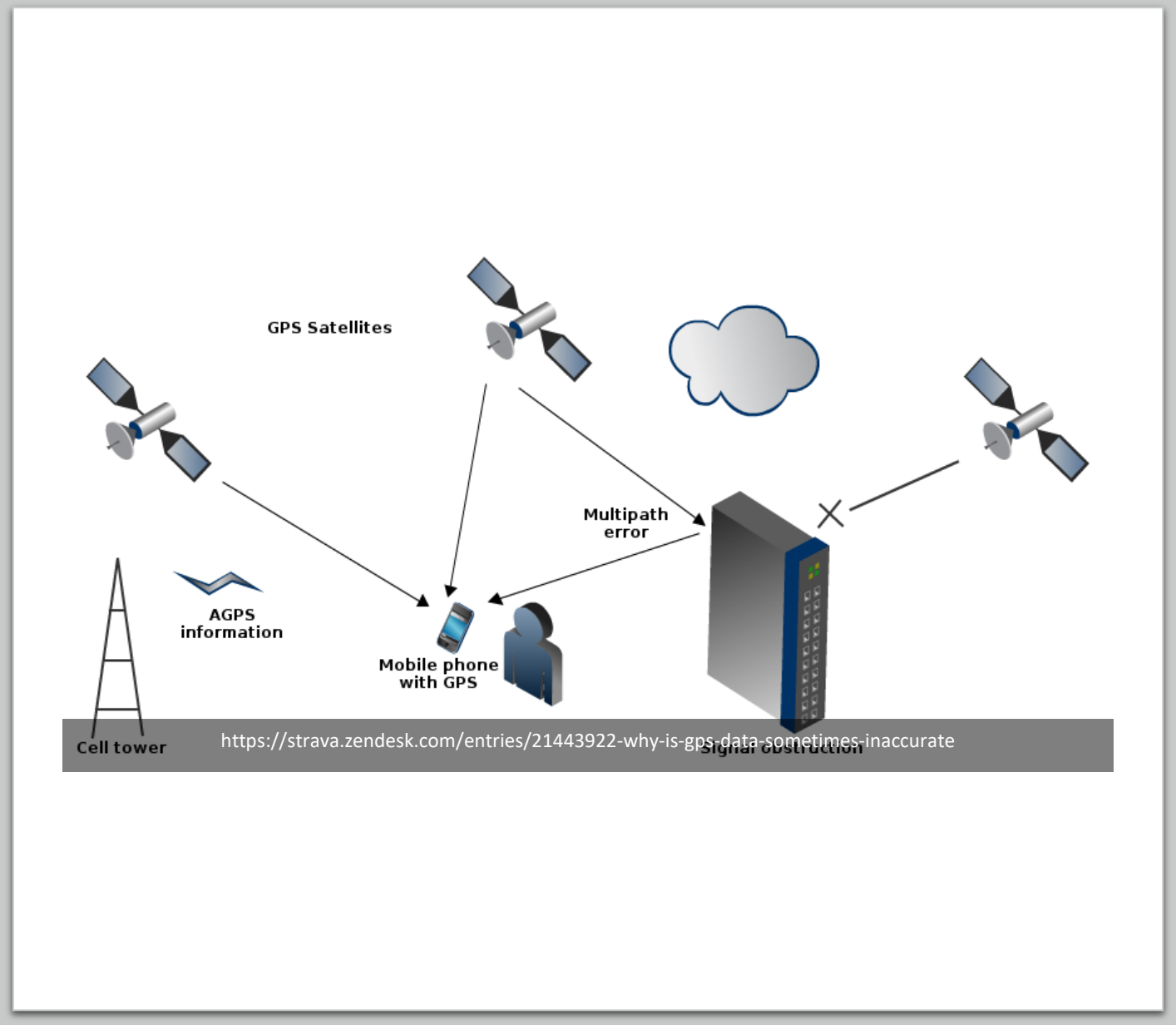
geoid-ellipsoidal-orthometric_height.jpg

From: University of Oklahoma

GPS Issues

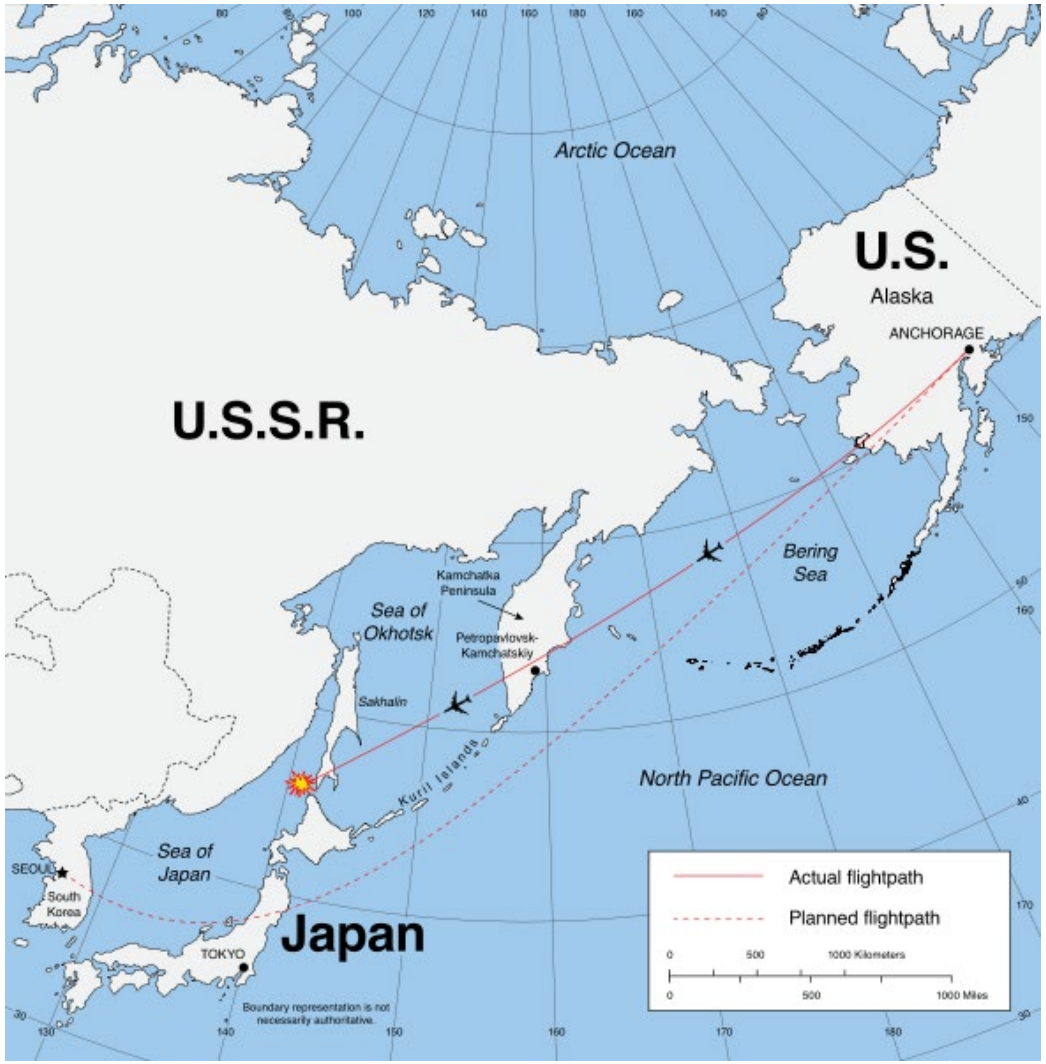
GPS radio signal can be affected by many factors, including:

- Clouds or other atmospheric conditions.
  - Speed of light varies in different media.
  - Can vary with temperature of medium
- Proximity to buildings and other structures, and even water.
- Terrain features like mountains.
- Earth's rotation.
- Current satellite configuration.



GPS Issues: Example

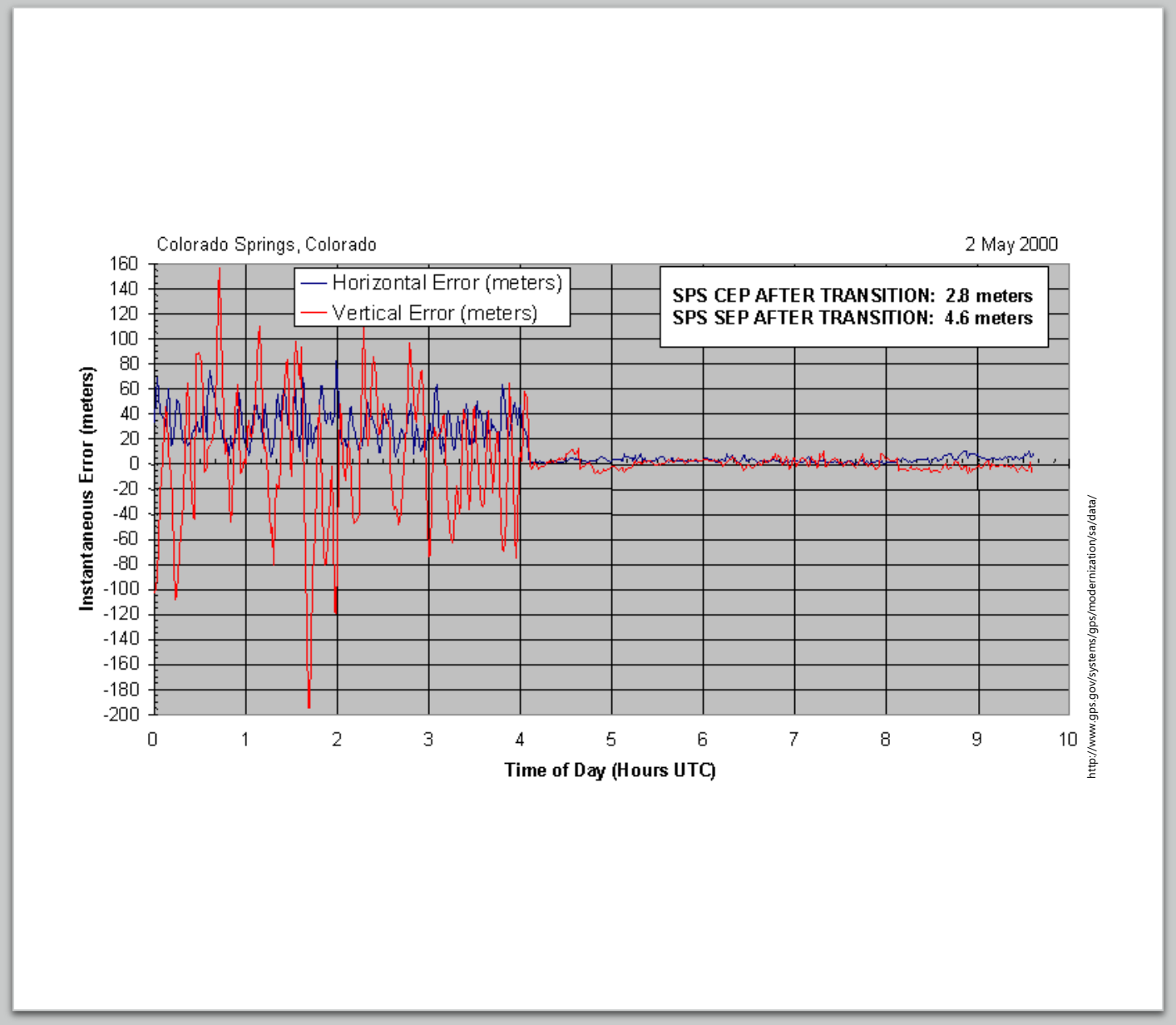
- On September 1, 1983, navigational errors cause KAL 007 to stray into prohibited Soviet airspace.
- Soviet MiG-23 interceptors shoot down KAL 007, killing all 269 people aboard.
- President Ronald Reagan orders U.S. military to make GPS system available for civilian use.
- [The Downing of Flight 007]



KAL007.png http://en.wikipedia.org/wiki/File:KAL007.svg

GPS Issues: Example II

- May 2, 2000: President Clinton orders U.S. military to cease intentional scrambling of GPS satellite signals used by civilians.
- Effectively improved GPS receiver accuracy by 10x.



GPS History and Applications

Check out Canada GIS

Global Positioning System - History

- **1978:** First GPS Satellite Launch
- **1983:** Reagan announces GPS will be available to civilians
- **1995:** GPS becomes fully operational

Block	Launch Period	Satellite launches				Currently in orbit and healthy
		Success	Failure	In preparation	Planned	
I	1978–1985	10	1	0	0	0
II	1989–1990	9	0	0	0	0
IIA	1990–1997	19	0	0	0	10
IIR	1997–2004	12	1	0	0	12
IIR-M	2005–2009	8	0	0	0	7
IIF	2010–2011	1	0	11	0	1
IIIA	2014–?	0	0	0	12	0
IIIB		0	0	0	8	0
IIIC		0	0	0	16	0
Total		59	2	11	36	30

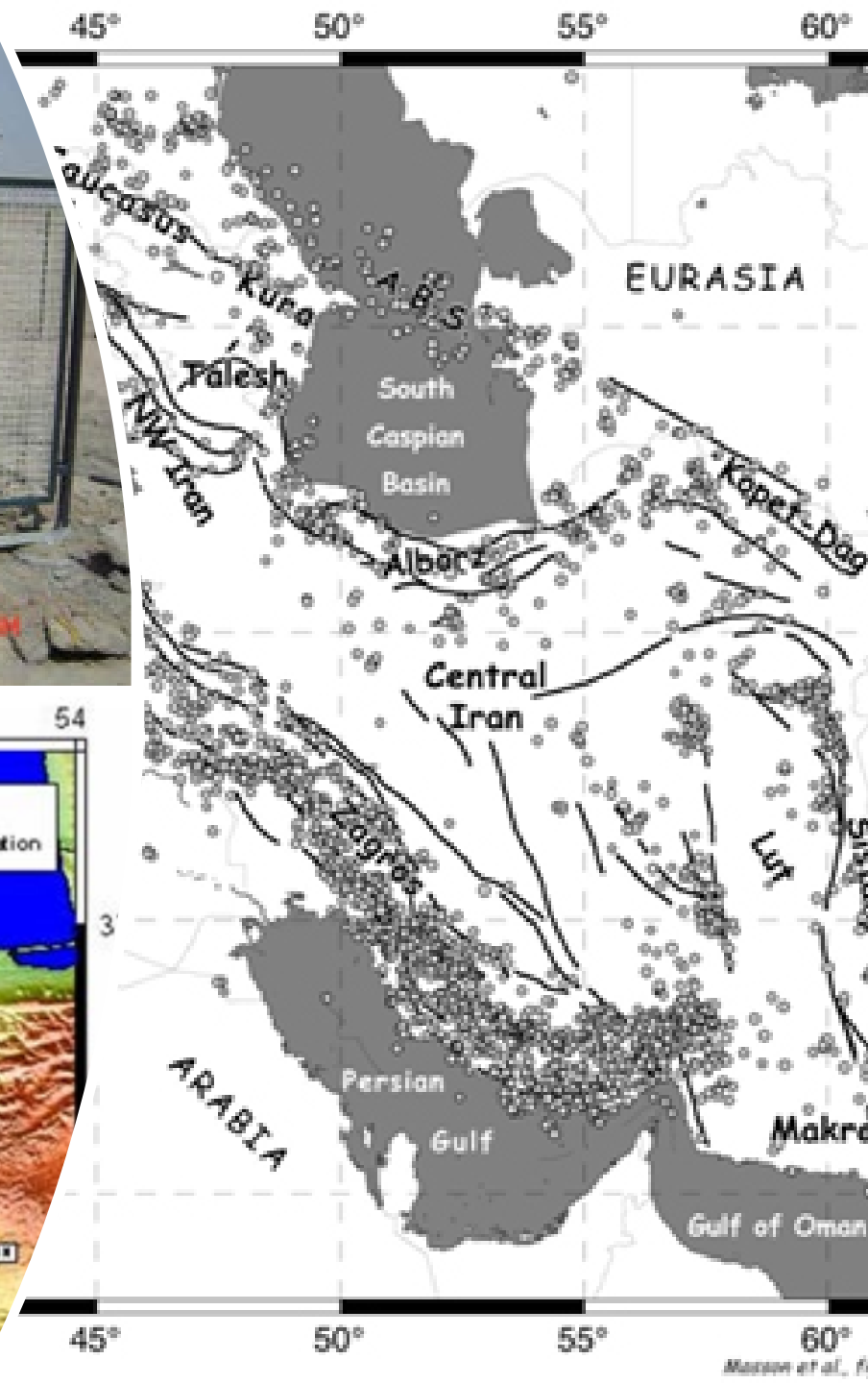
GPS Applications

GPS Applications

- Precision Agriculture

GPS Applications

Deformation and earthquake monitoring



GPS Applications

Announcements

- Thanks for being patient with the asynchronous lecture format from Tuesday! If you haven't already done so, you can watch the Tuesday lecture (broken up into two videos) on Echo360.
- Some of the midterm information in lecture 5b was out of date.
  - The midterm will automatically open on Friday June 16th at 12:01 AM, and close on Friday June 23rd at 11:59PM.
  - This gives you about 8 days to complete it.
- Next Tuesday will also be asynchronous; I have last-minute plans and I'll be in airports on Tuesday. I'll post the recorded lecture before the normal lecture time on Tuesday.

For today

- Review spatial data operations we have met so far (this deck)
- Midterm review (deck 6)

Spatial Data Operations

Selection and Geoprocessing

Two analytical approaches

Selection

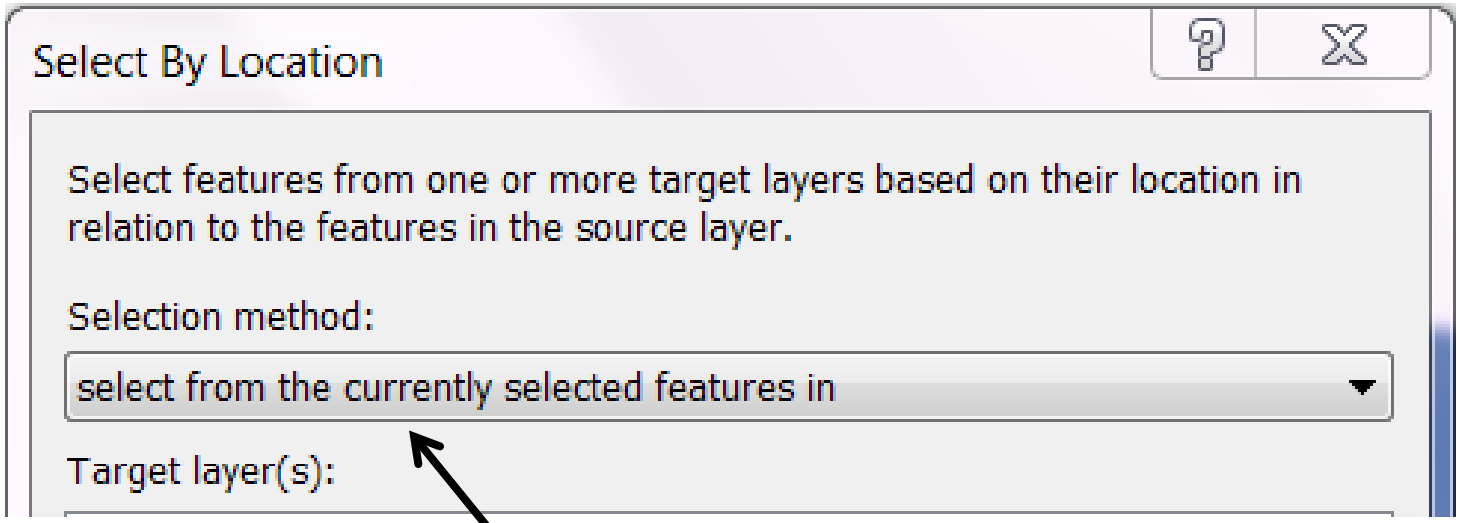
- Creates subsets of features
  - By attributes or location
- Does not create new features
- Does not alter the location data of existing features.

Geoprocessing

- Can create subsets of features
  - Based on location
- May create new features
  - E.g. buffers
- May alter existing features
  - ArcMap typically saves the output of geoprocessing to a new layer.

Review: Selection options

- **One warning**:
- ArcMap will remember your previous choice in the selection method
- If you are trying to create a new selection and nothing happens, check there first



Only works if you already have something selected!

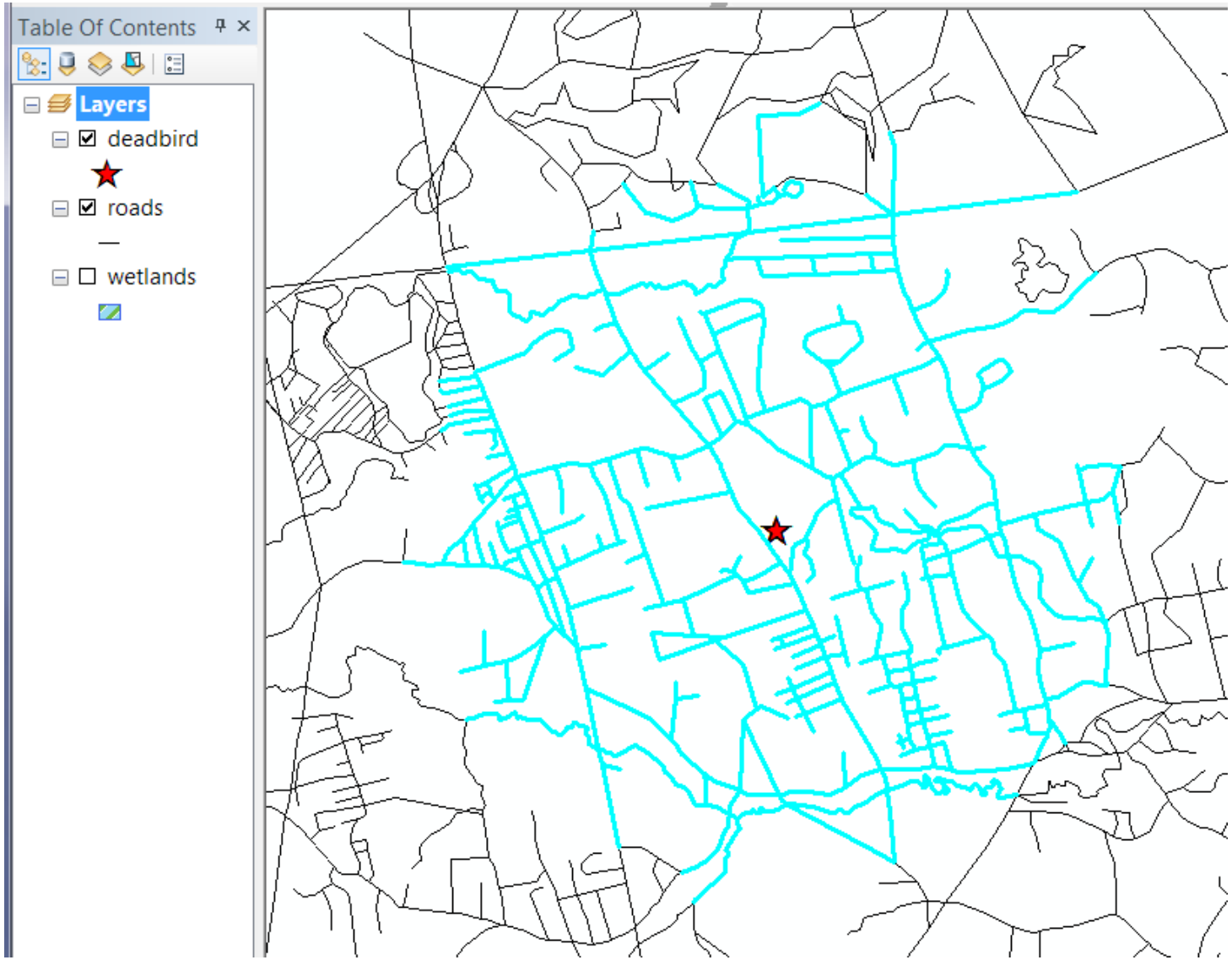
Thinking about a dead bird…

- Compare selection vs. geoprocessing approaches.

Review: **Selection** vs. Geoprocessing

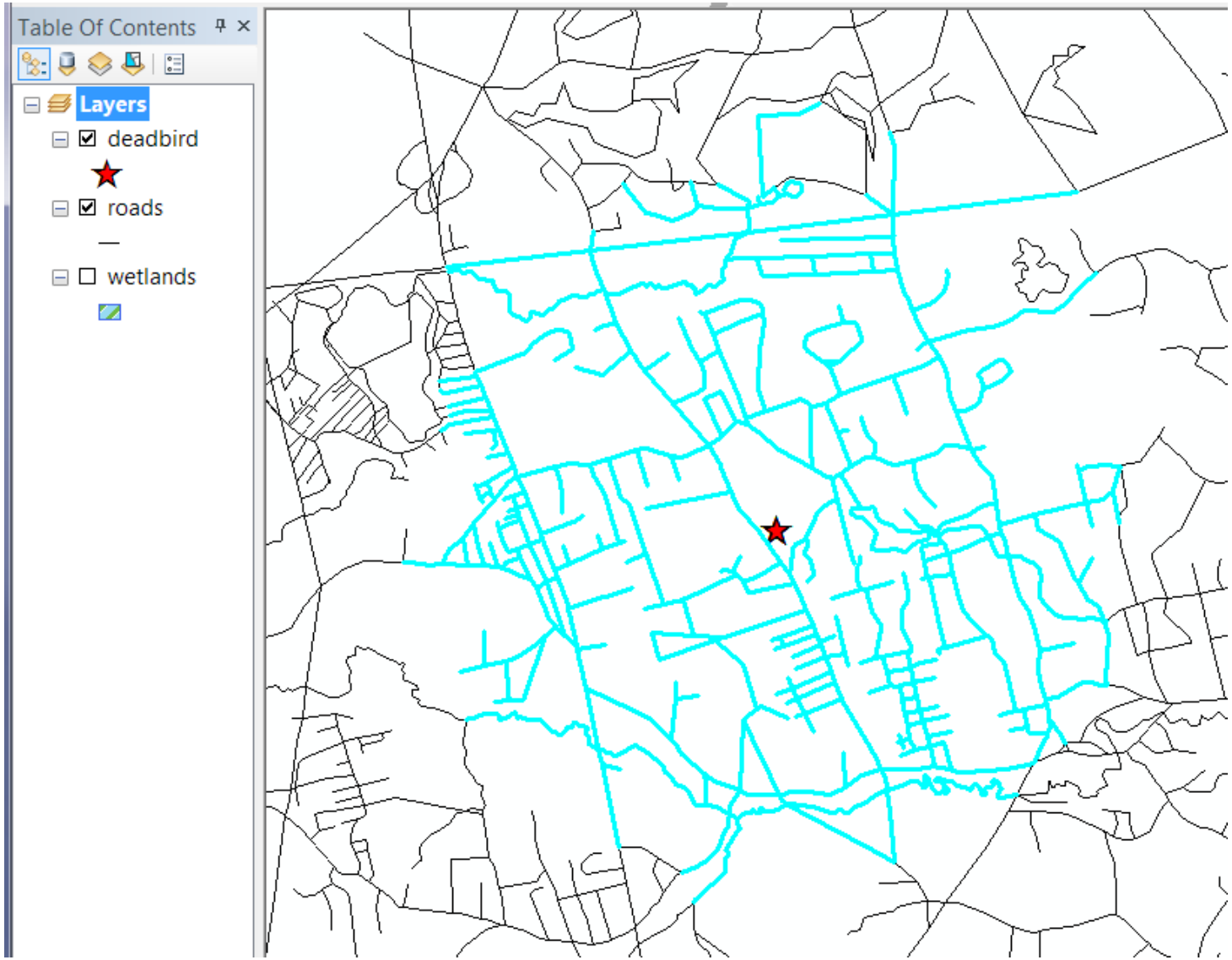
- How many roads are within 2 km of the dead bird?

- What are the names of the roads within 2 km of the dead bird?



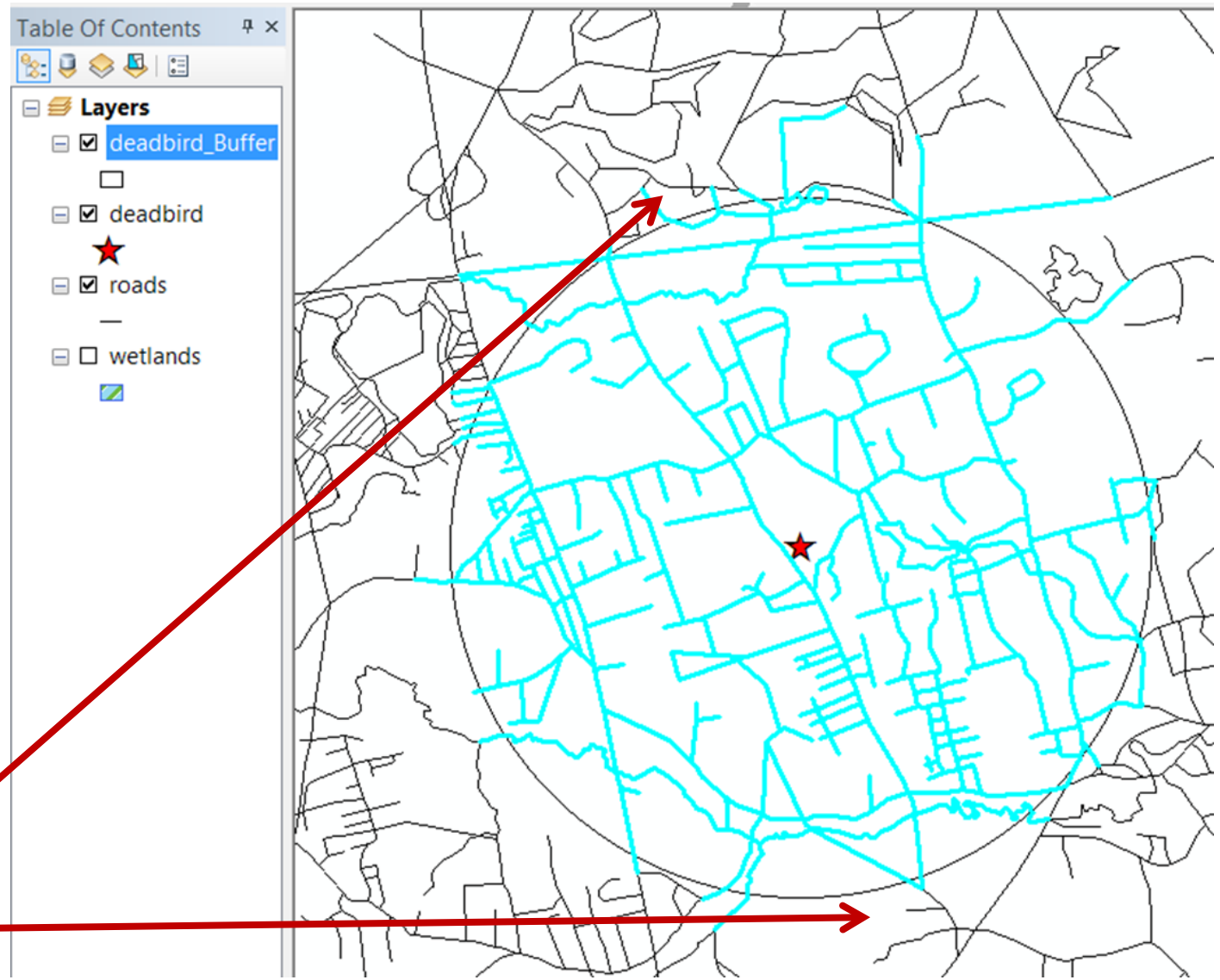
Review: Selection vs. Geoprocessing

- What is the <u>total length</u> of roads within 2 km of the dead bird?
- Should we use a selection or a geoprocessing approach?



Review: **Selection** vs. Geoprocessing

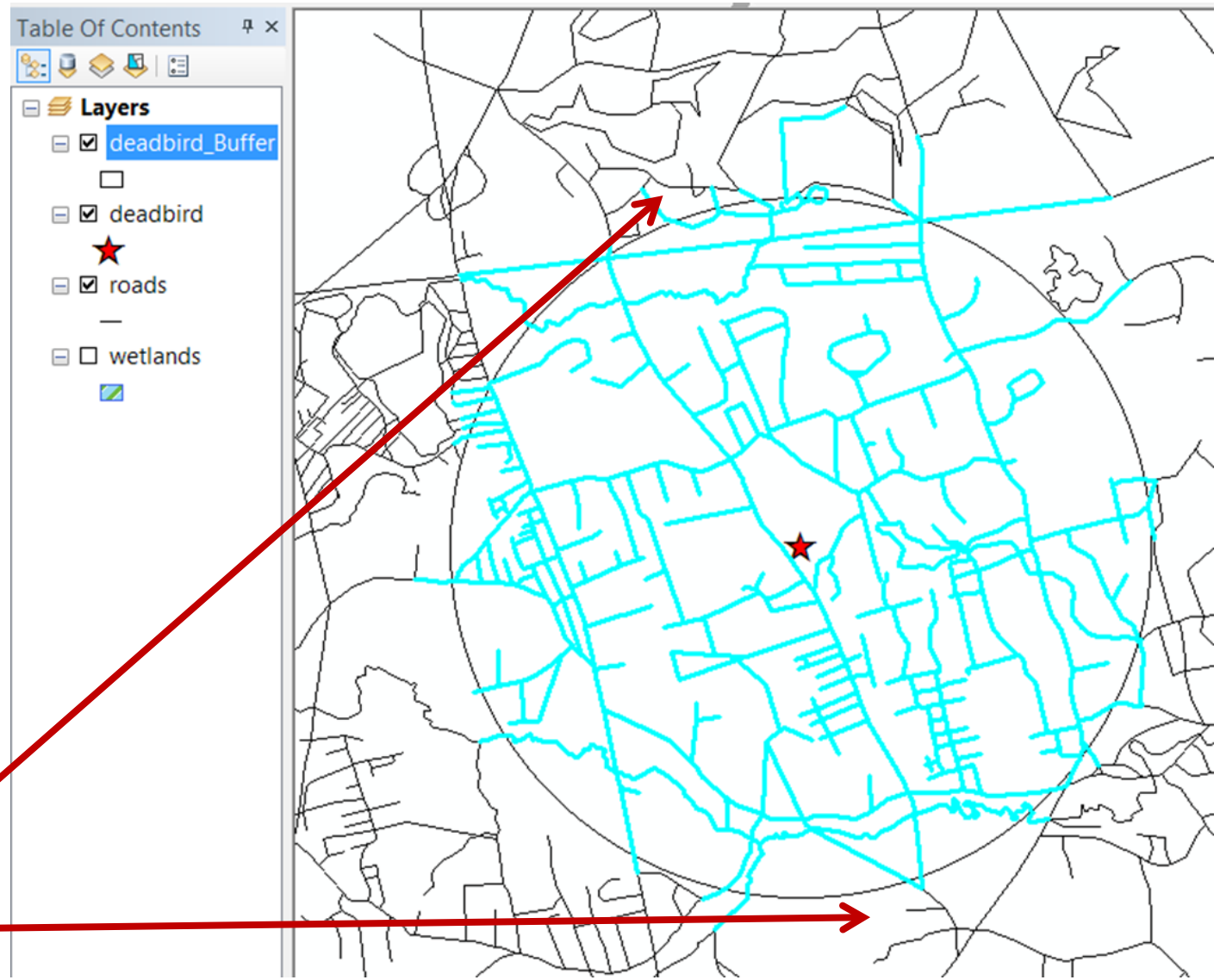
- What is the <u>total length</u> of roads within 2 km of the dead bird?
- Selection doesn't seem helpful here.



Road segments outside of 2 km: length will be over-estimated

Review: Selection vs. **Geoprocessing**

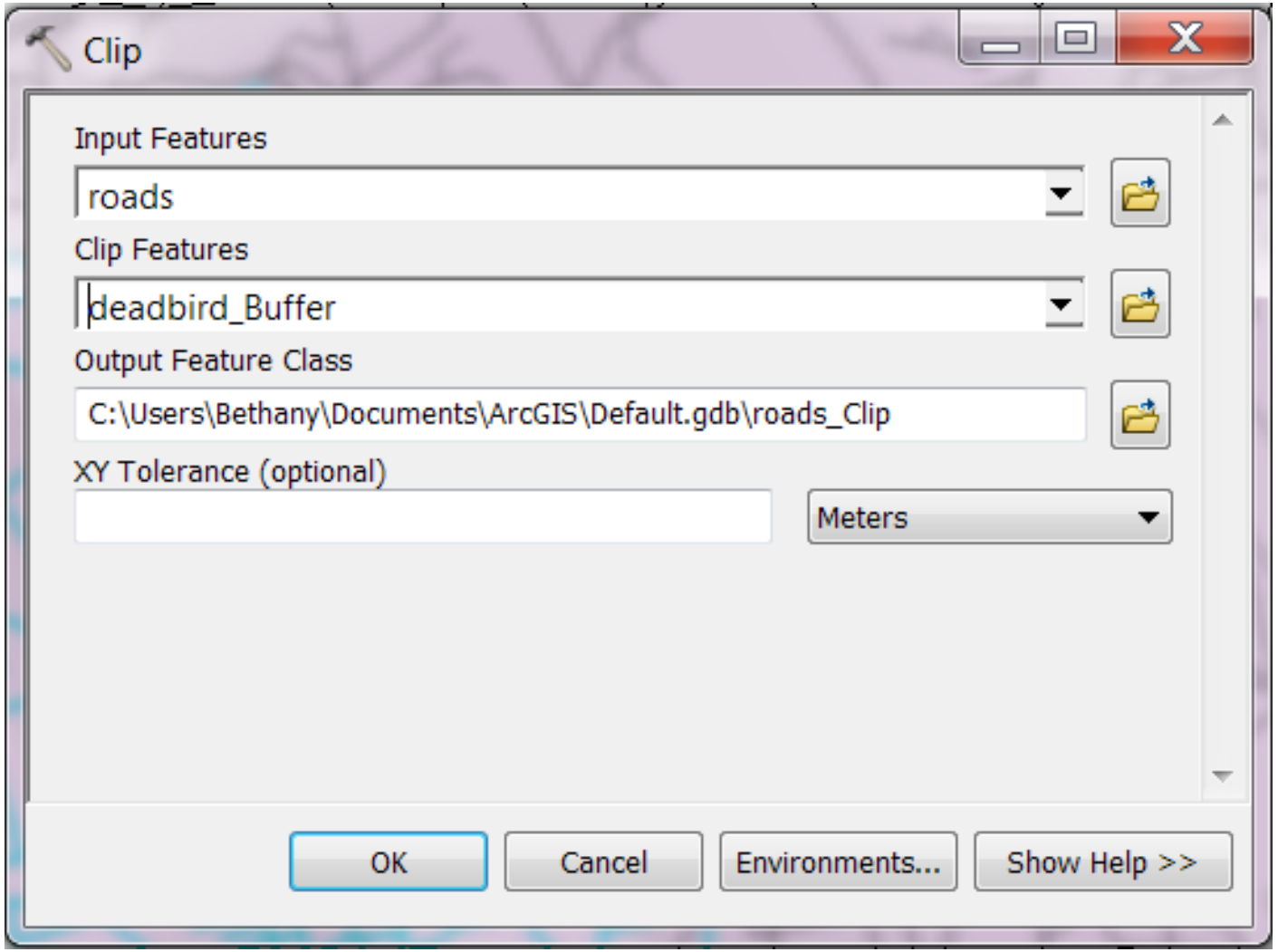
- We need to **alter** the location data of some of the selected roads.



Road segments outside of 2 km: length will be over-estimated

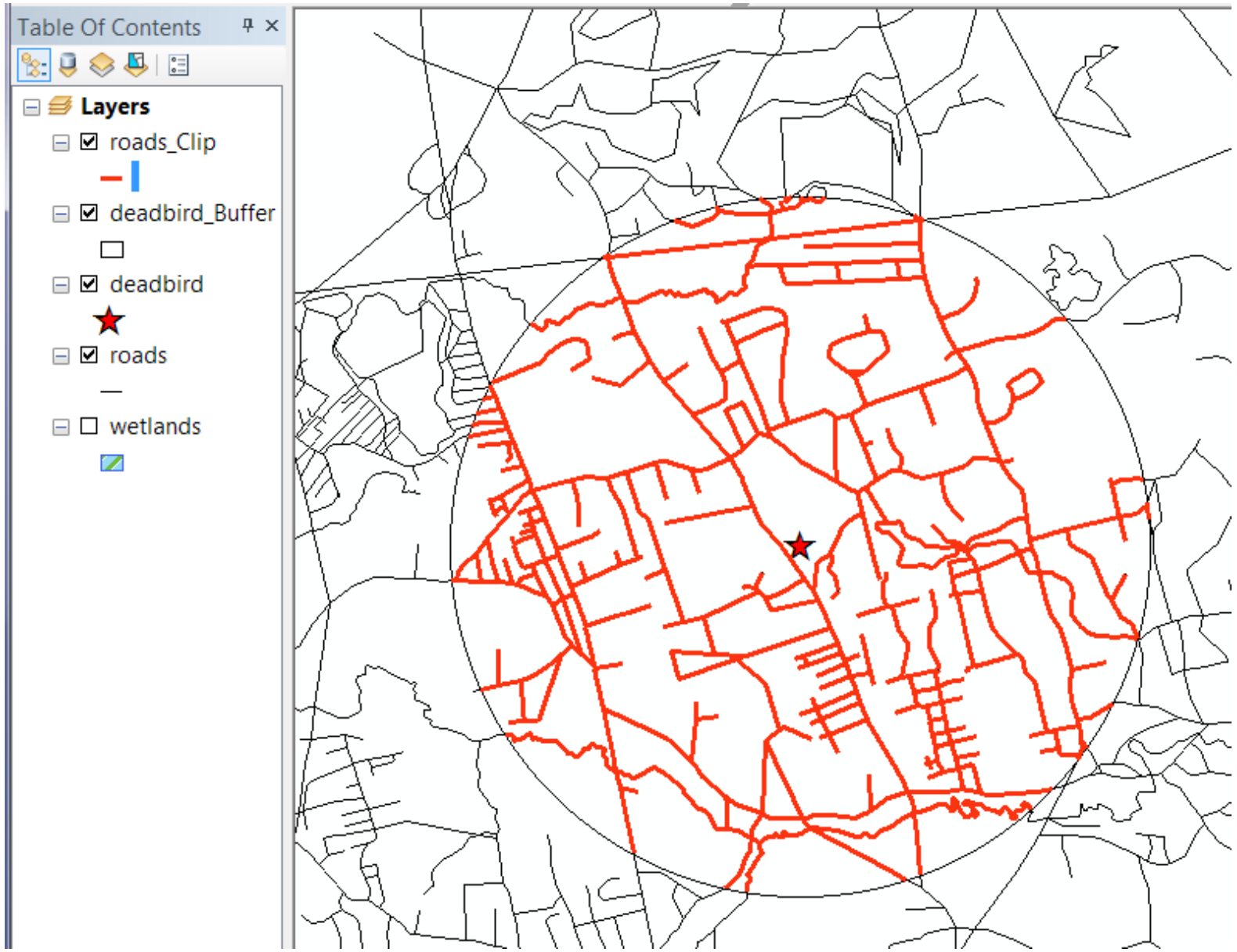
Review: Selection vs. **Geoprocessing**

- What is the <u>total length</u> of roads within 2 km of the dead bird?
- **Clip** to the rescue!



Review: Selection vs. **Geoprocessing**

- What is the <u>total length</u> of roads within 2 km of the dead bird?
- **Clip** to the rescue!
- How do we calculate length of the clipped roads?



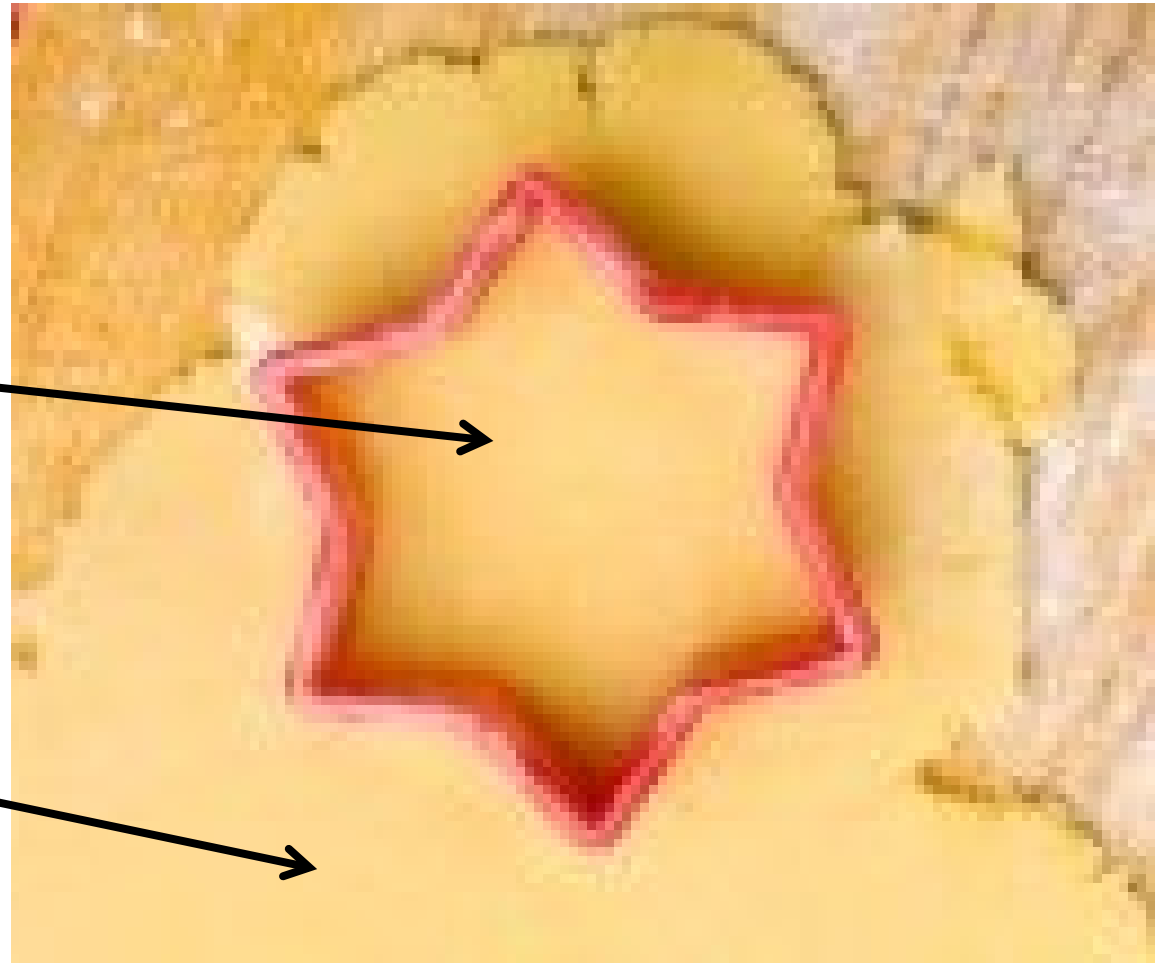
Review: Selection and Geoprocessing

Common Geoprocessing Operations

Clip and Erase

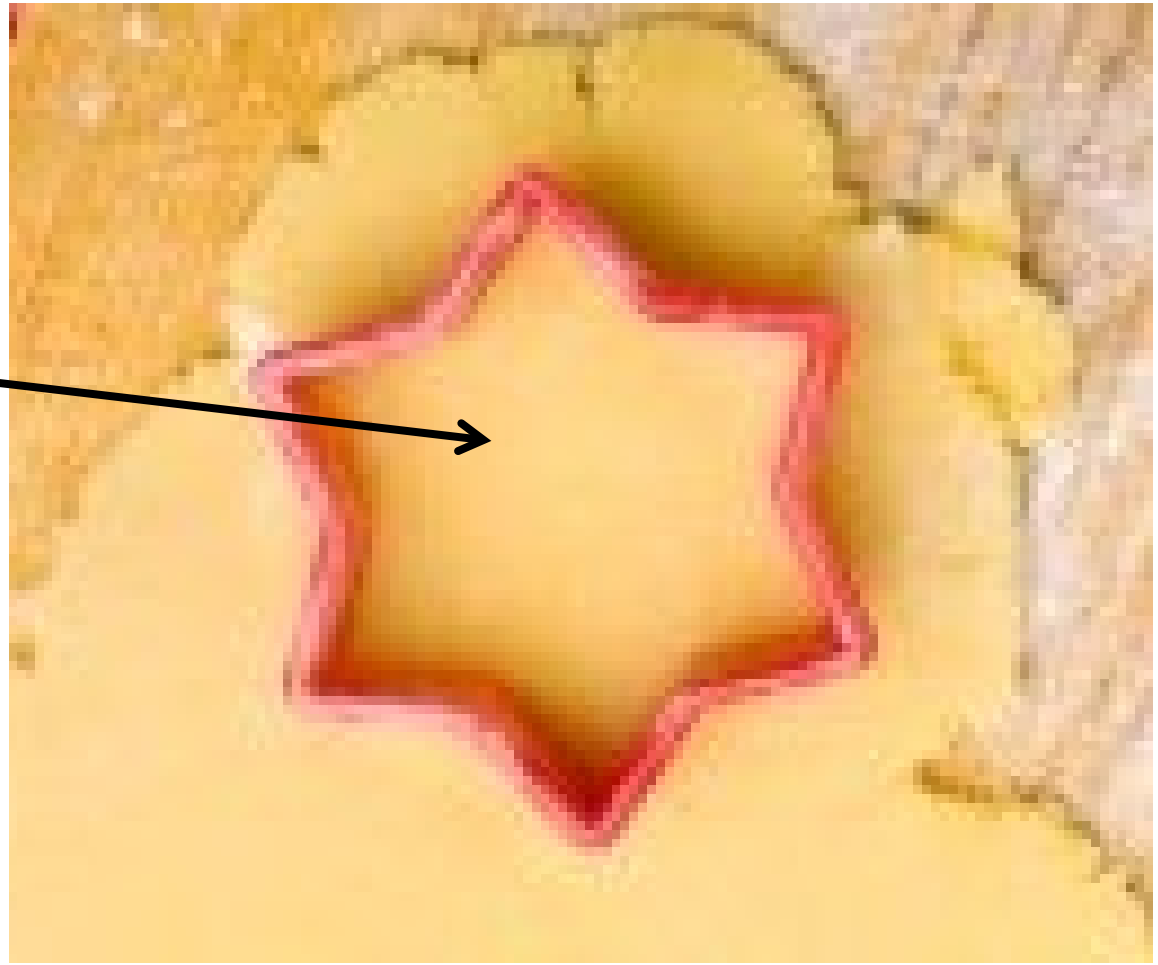
Clip keeps the info inside the shape

Erase keeps the info outside the shape



Intersect

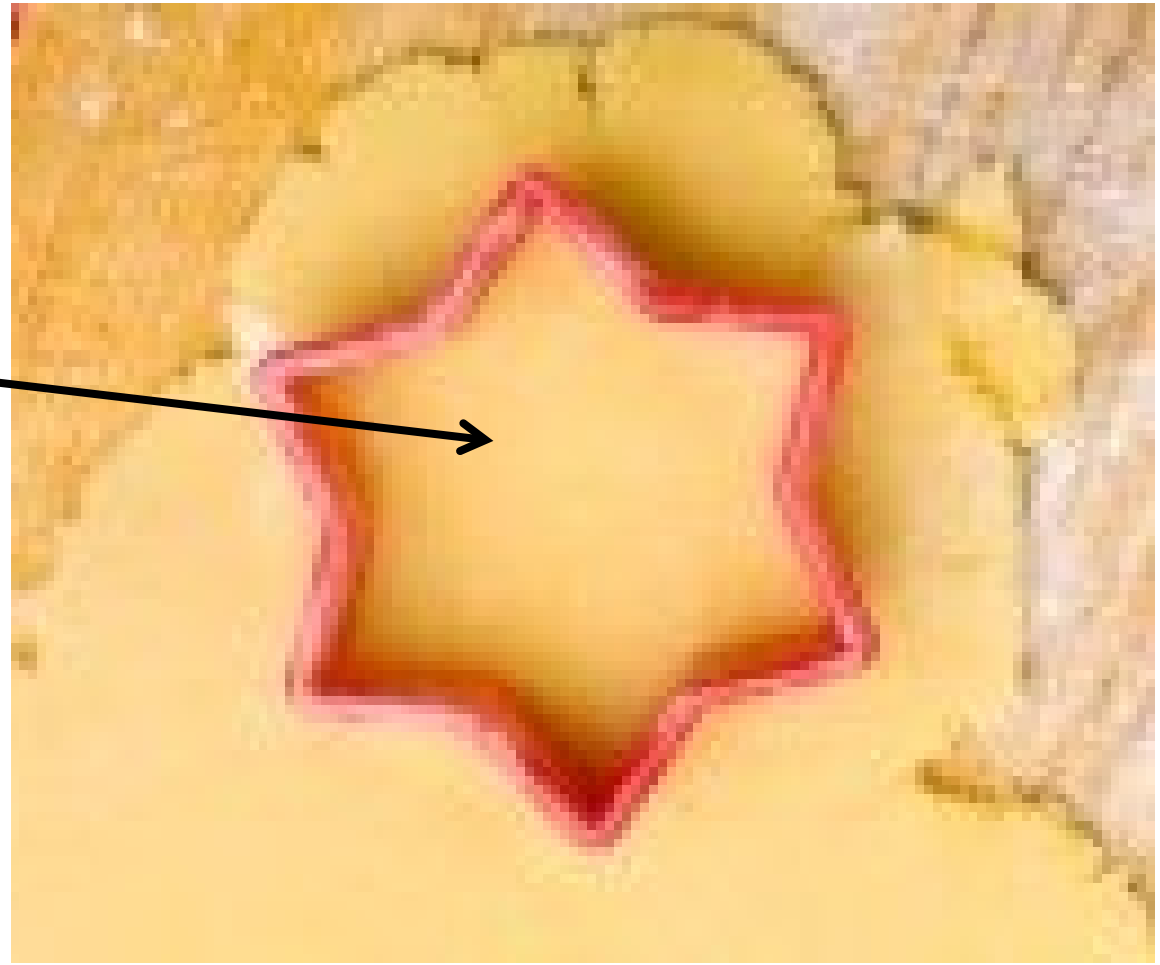
Intersect is like a clip (you end up with the inside), except you retain the attributes from BOTH shapefiles



Intersect

Intersect is like a clip (you end up with the inside), except you retain the attributes from BOTH shapefiles

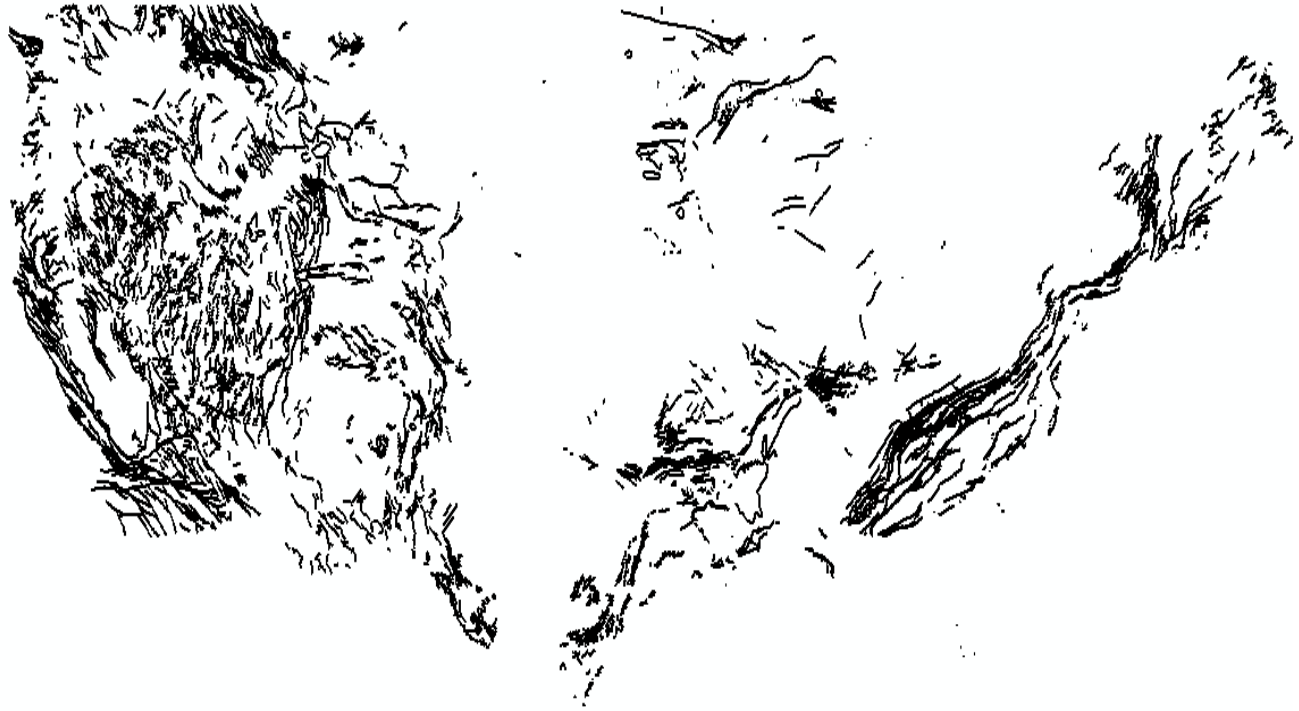
More at the end of the deck.



Buffer and Dissolve

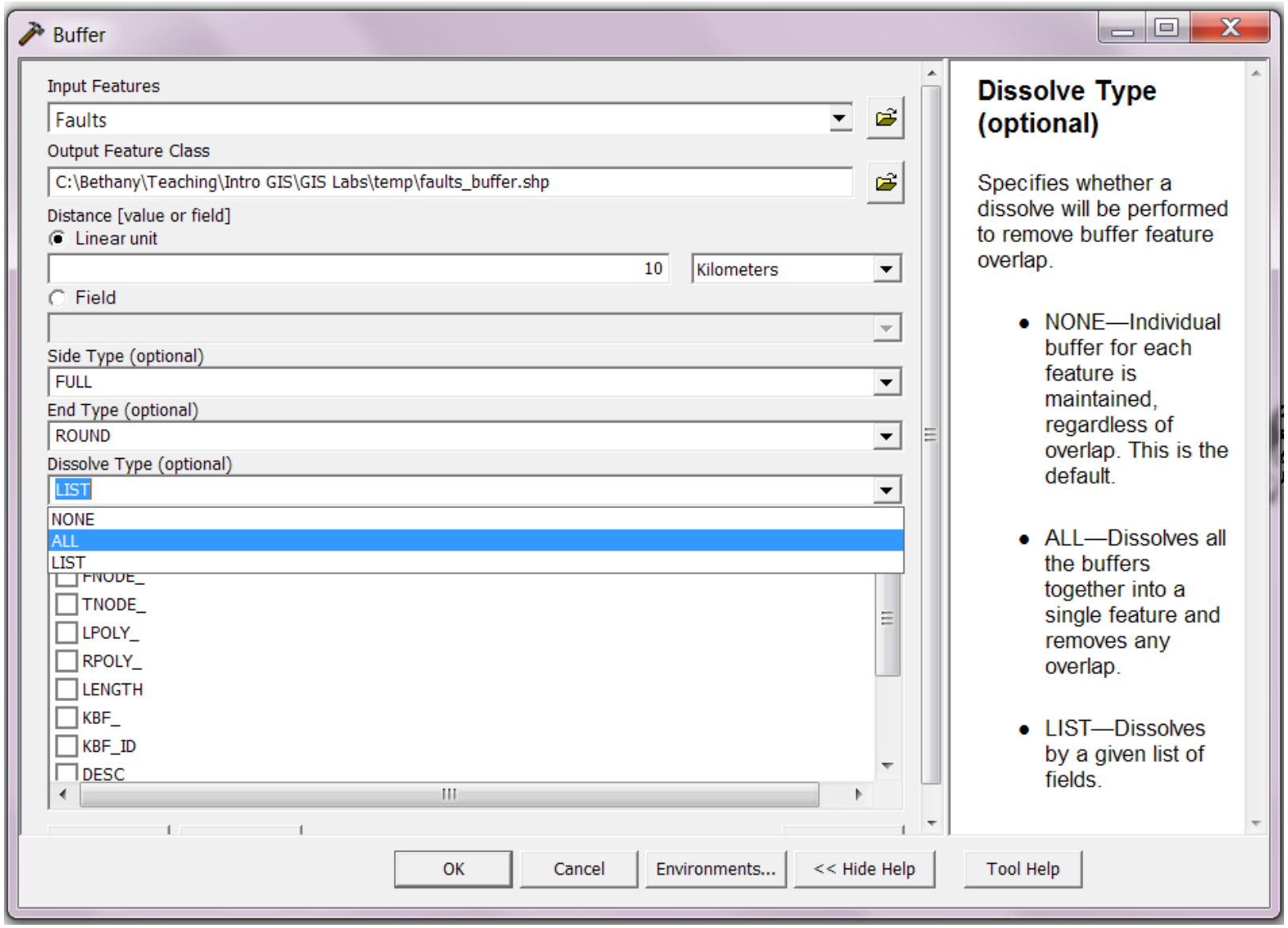
What is the total land area within 5k of all US highways?

Is this a selection or geoprocessing question?



Buffer!

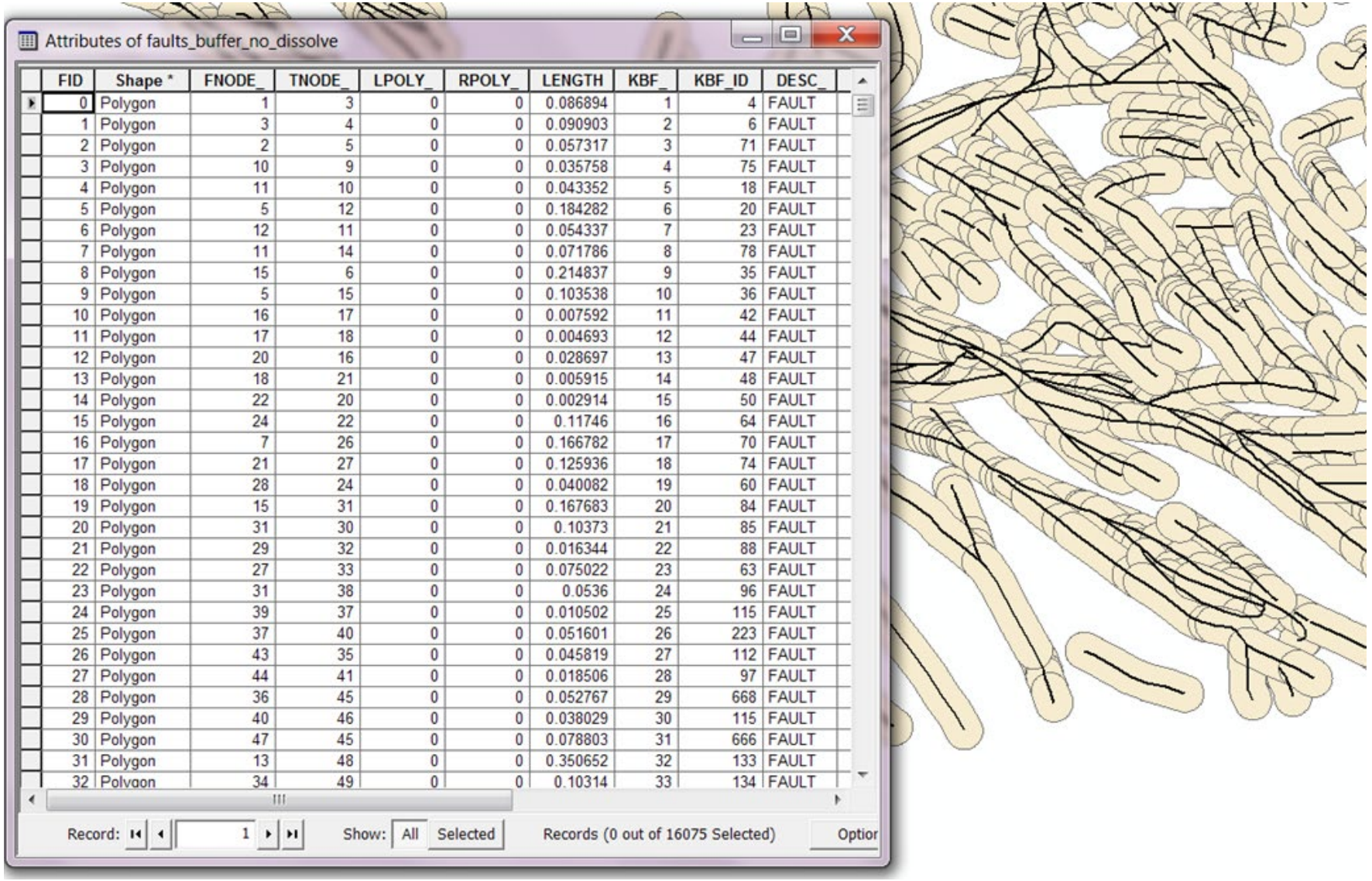
Let's try the default: don't dissolve



Buffer!

New buffer polygons overlap.

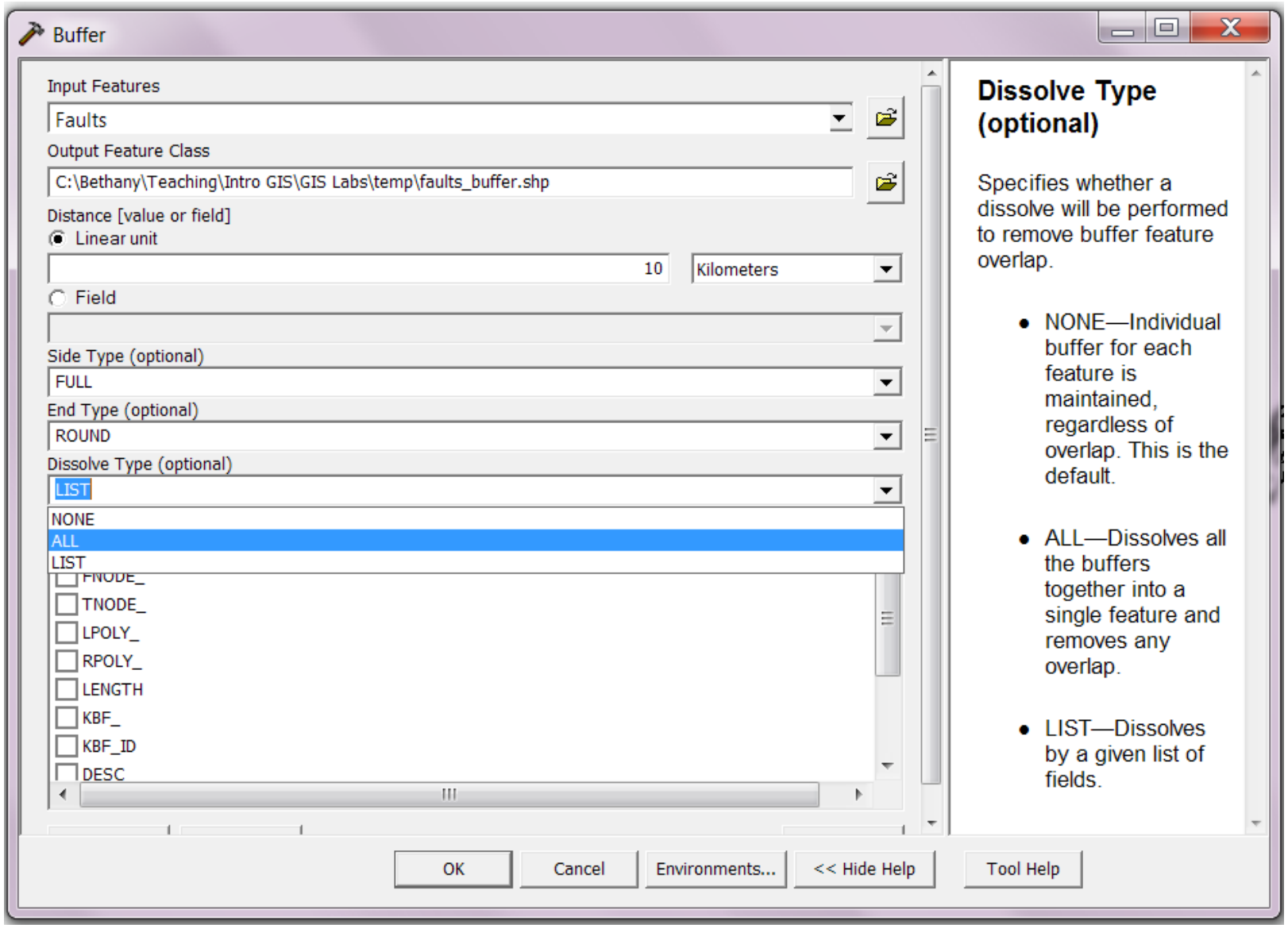
This is probably not what we want…



FID	Shape *	FNODE_	TNODE_	LPOLY_	RPOLY_	LENGTH	KBF_	KBF_ID	DESC_
0	Polygon	1	3	0	0	0.086894	1	4	FAULT
1	Polygon	3	4	0	0	0.090903	2	6	FAULT
2	Polygon	2	5	0	0	0.057317	3	71	FAULT
3	Polygon	10	9	0	0	0.035758	4	75	FAULT
4	Polygon	11	10	0	0	0.043352	5	18	FAULT
5	Polygon	5	12	0	0	0.184282	6	20	FAULT
6	Polygon	12	11	0	0	0.054337	7	23	FAULT
7	Polygon	11	14	0	0	0.071786	8	78	FAULT
8	Polygon	15	6	0	0	0.214837	9	35	FAULT
9	Polygon	5	15	0	0	0.103538	10	36	FAULT
10	Polygon	16	17	0	0	0.007592	11	42	FAULT
11	Polygon	17	18	0	0	0.004693	12	44	FAULT
12	Polygon	20	16	0	0	0.028697	13	47	FAULT
13	Polygon	18	21	0	0	0.005915	14	48	FAULT
14	Polygon	22	20	0	0	0.002914	15	50	FAULT
15	Polygon	24	22	0	0	0.11746	16	64	FAULT
16	Polygon	7	26	0	0	0.166782	17	70	FAULT
17	Polygon	21	27	0	0	0.125936	18	74	FAULT
18	Polygon	28	24	0	0	0.040082	19	60	FAULT
19	Polygon	15	31	0	0	0.167683	20	84	FAULT
20	Polygon	31	30	0	0	0.10373	21	85	FAULT
21	Polygon	29	32	0	0	0.016344	22	88	FAULT
22	Polygon	27	33	0	0	0.075022	23	63	FAULT
23	Polygon	31	38	0	0	0.0536	24	96	FAULT
24	Polygon	39	37	0	0	0.010502	25	115	FAULT
25	Polygon	37	40	0	0	0.051601	26	223	FAULT
26	Polygon	43	35	0	0	0.045819	27	112	FAULT
27	Polygon	44	41	0	0	0.018506	28	97	FAULT
28	Polygon	36	45	0	0	0.052767	29	668	FAULT
29	Polygon	40	46	0	0	0.038029	30	115	FAULT
30	Polygon	47	45	0	0	0.078803	31	666	FAULT
31	Polygon	13	48	0	0	0.350652	32	133	FAULT
32	Polygon	34	49	0	0	0.10314	33	134	FAULT

Buffer!

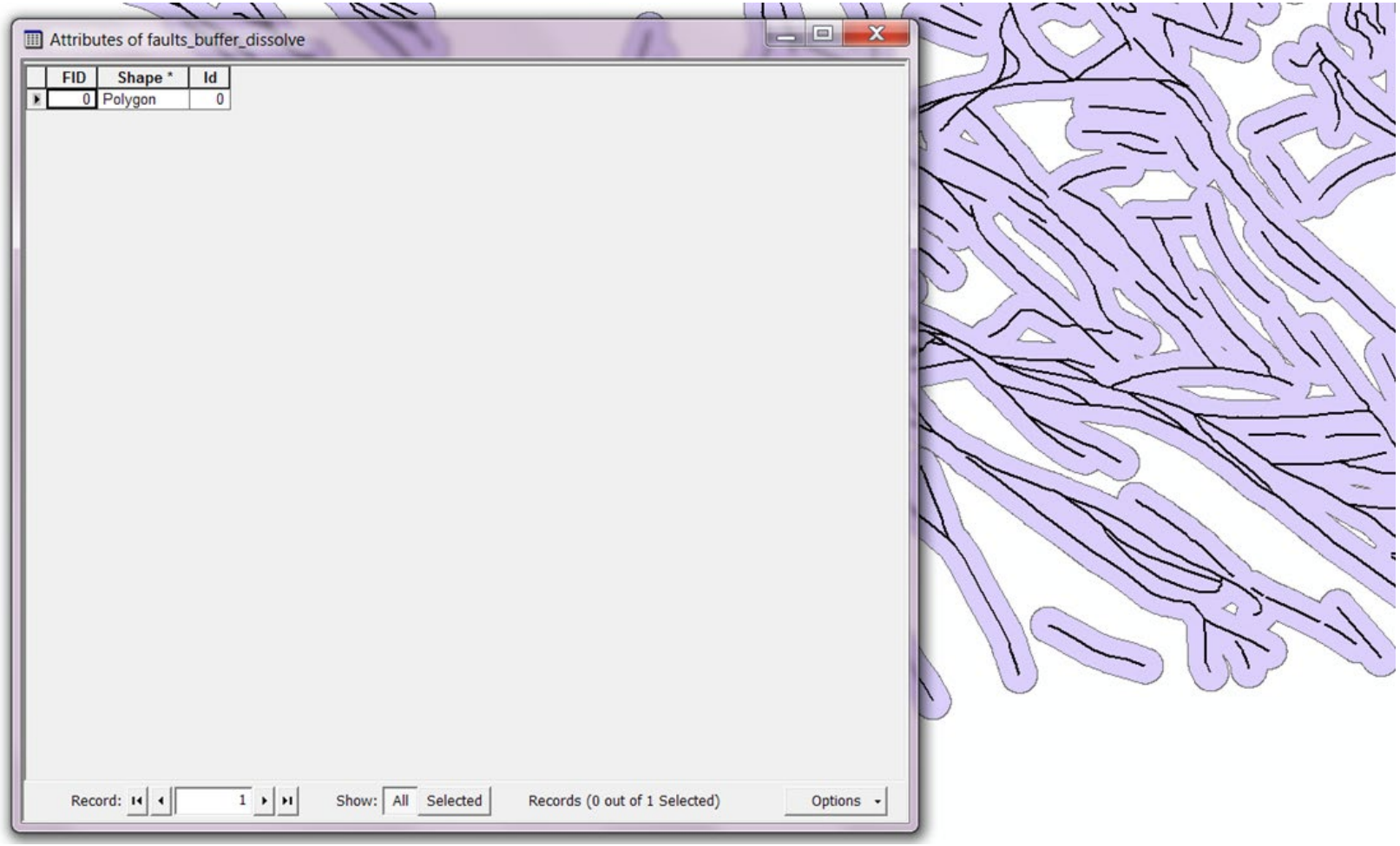
Dissolve all polygons!



Buffer!

No overlap.

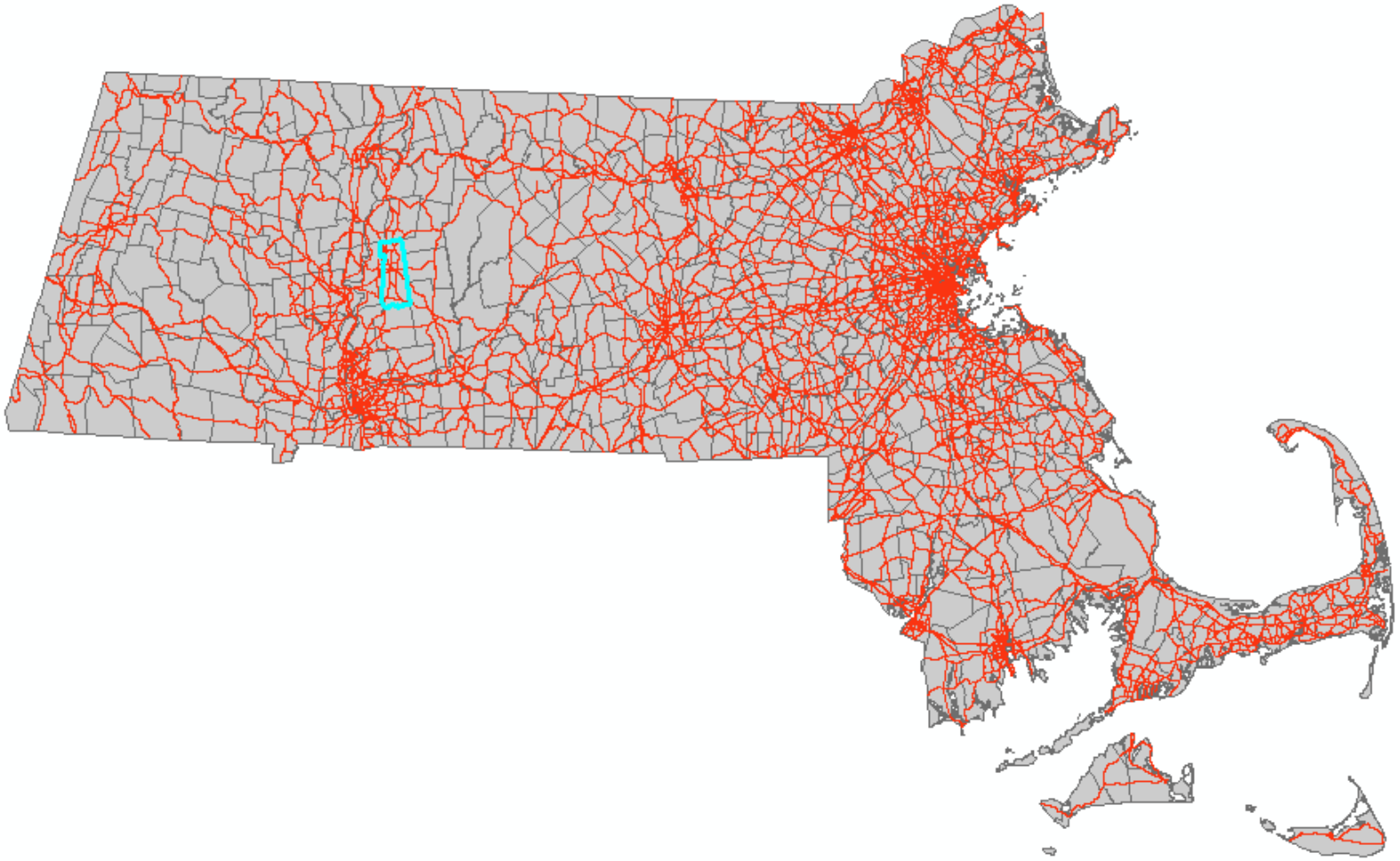
Better?



Intersections

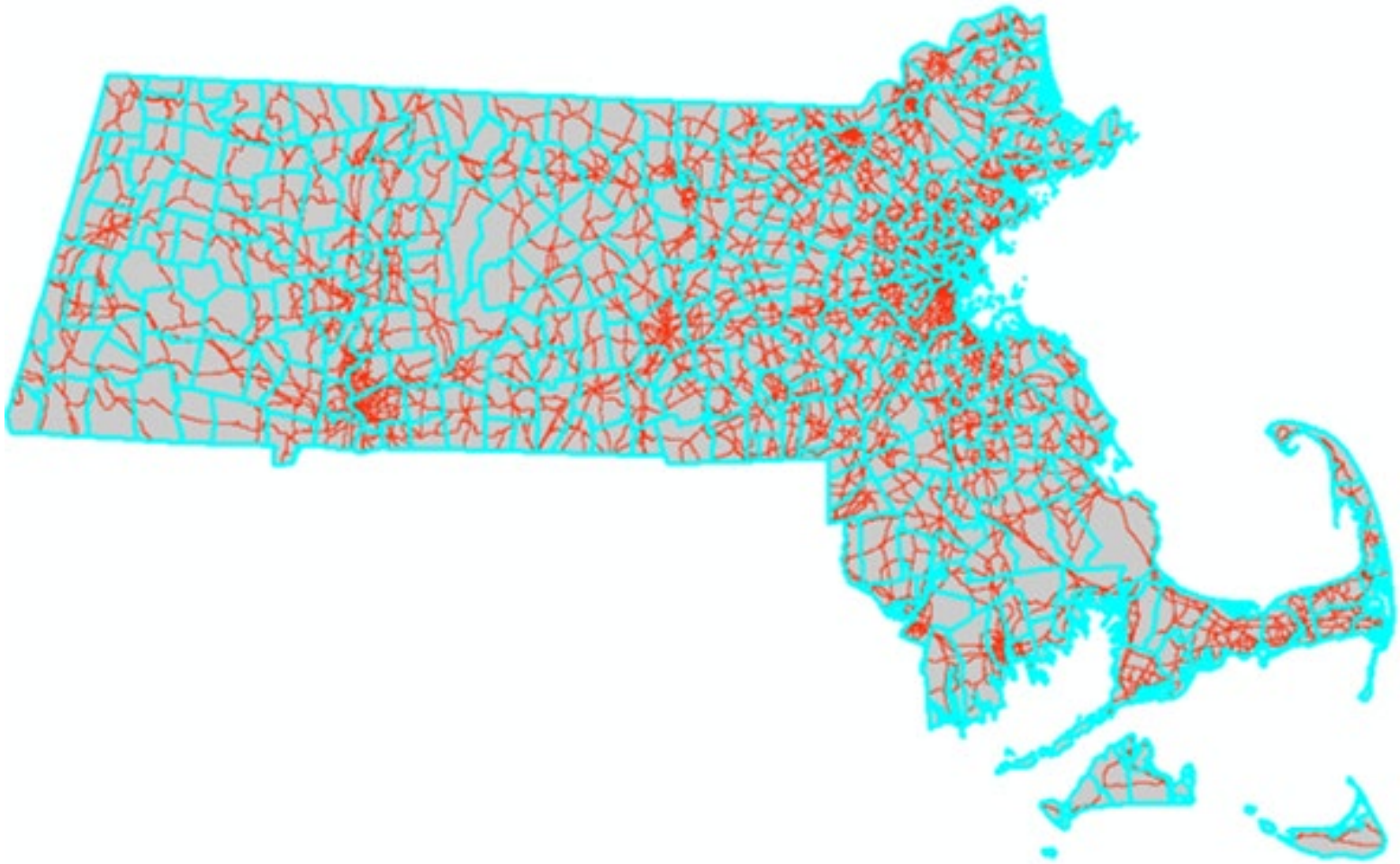
What is the total length of roads in Amherst?

- What steps could you use to find out?



What is the total length of roads in each town in MA?

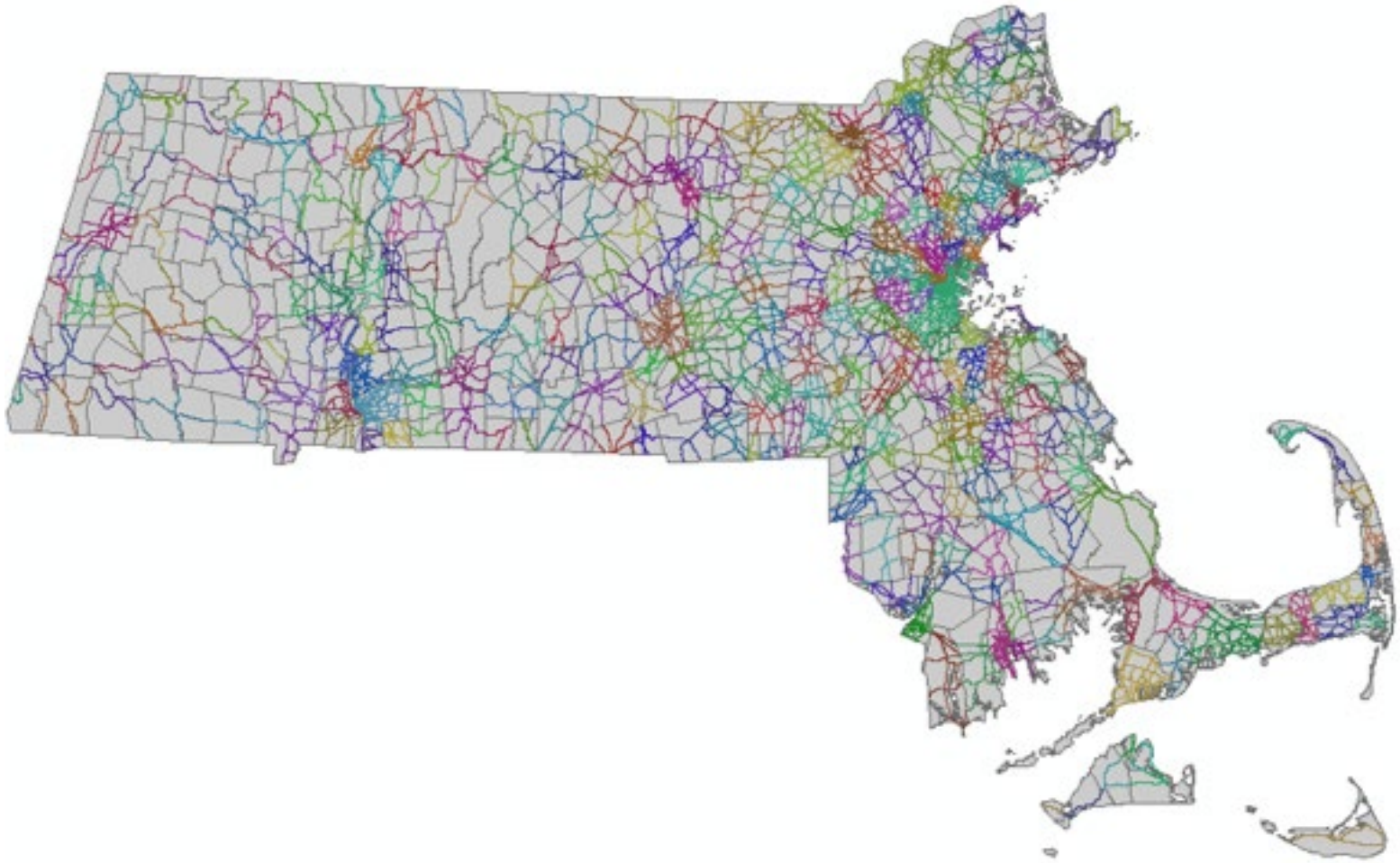
- More complicated question.
- How could you find out?



Road segments within towns

- You have two shapefiles:

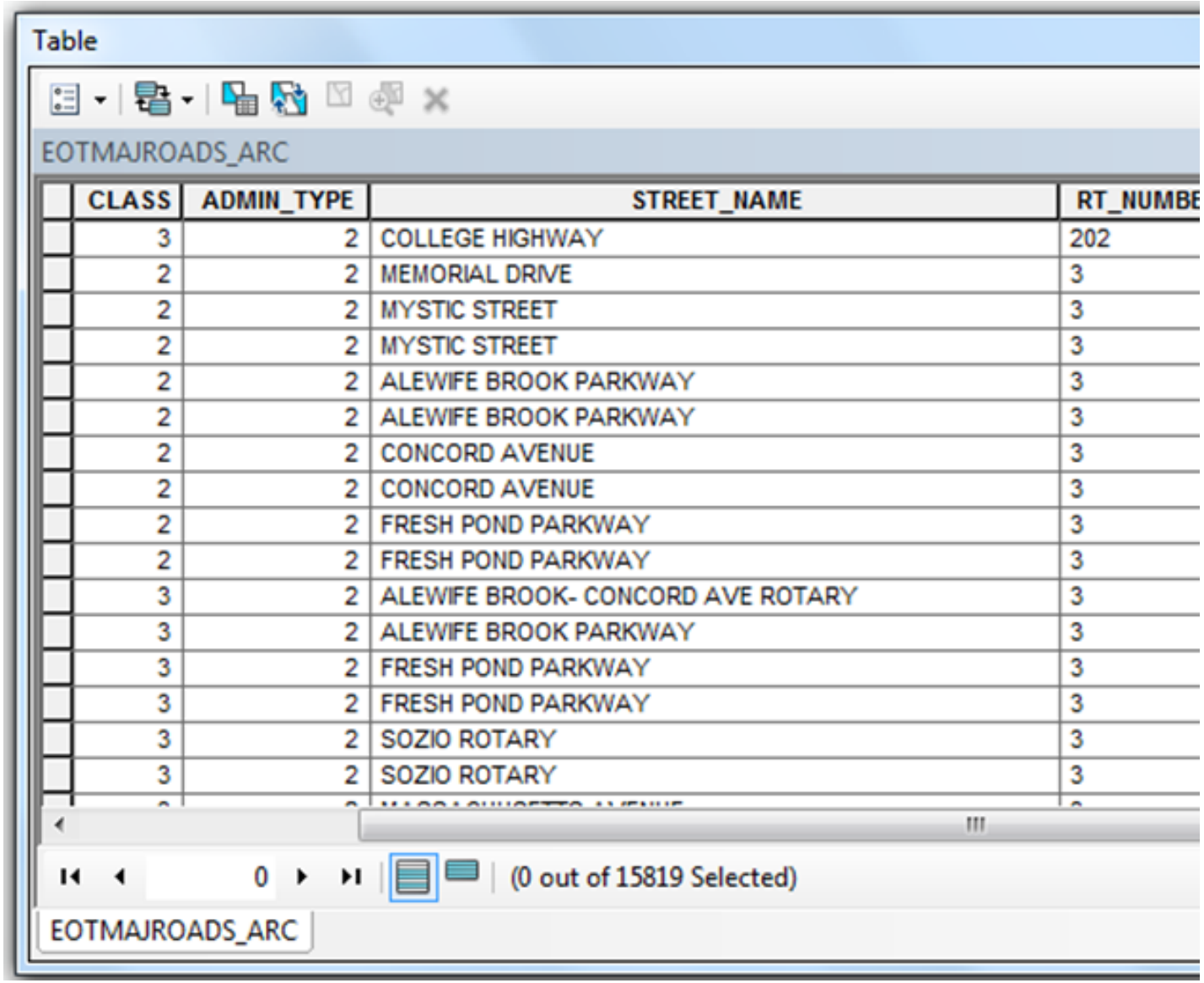
1. Towns
2. Roads



Major Roads in MA

Attribute table **before** intersection

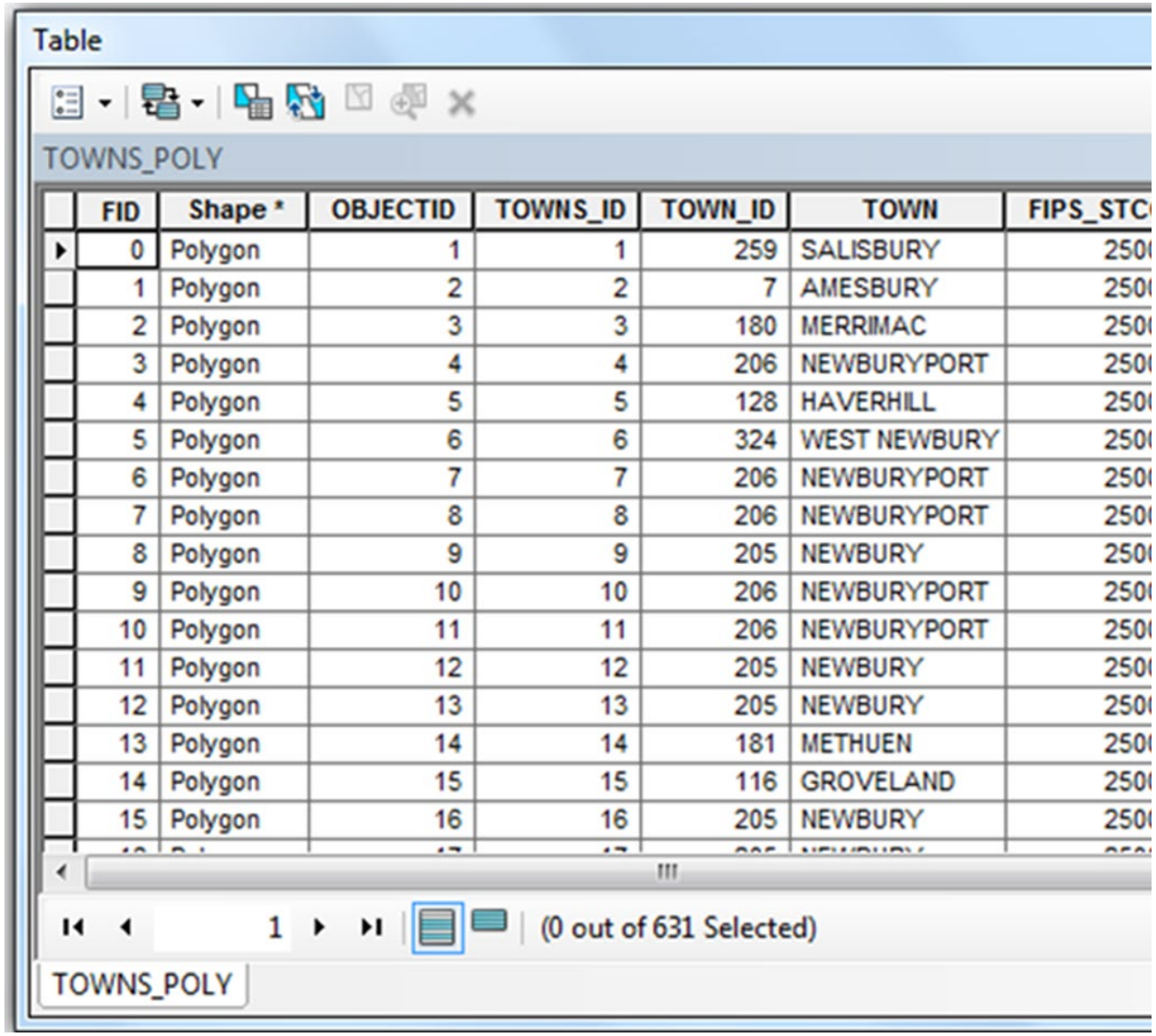
- There are 15819 major roads



Towns in MA

Attribute table **before** intersection

- There are 631 towns.

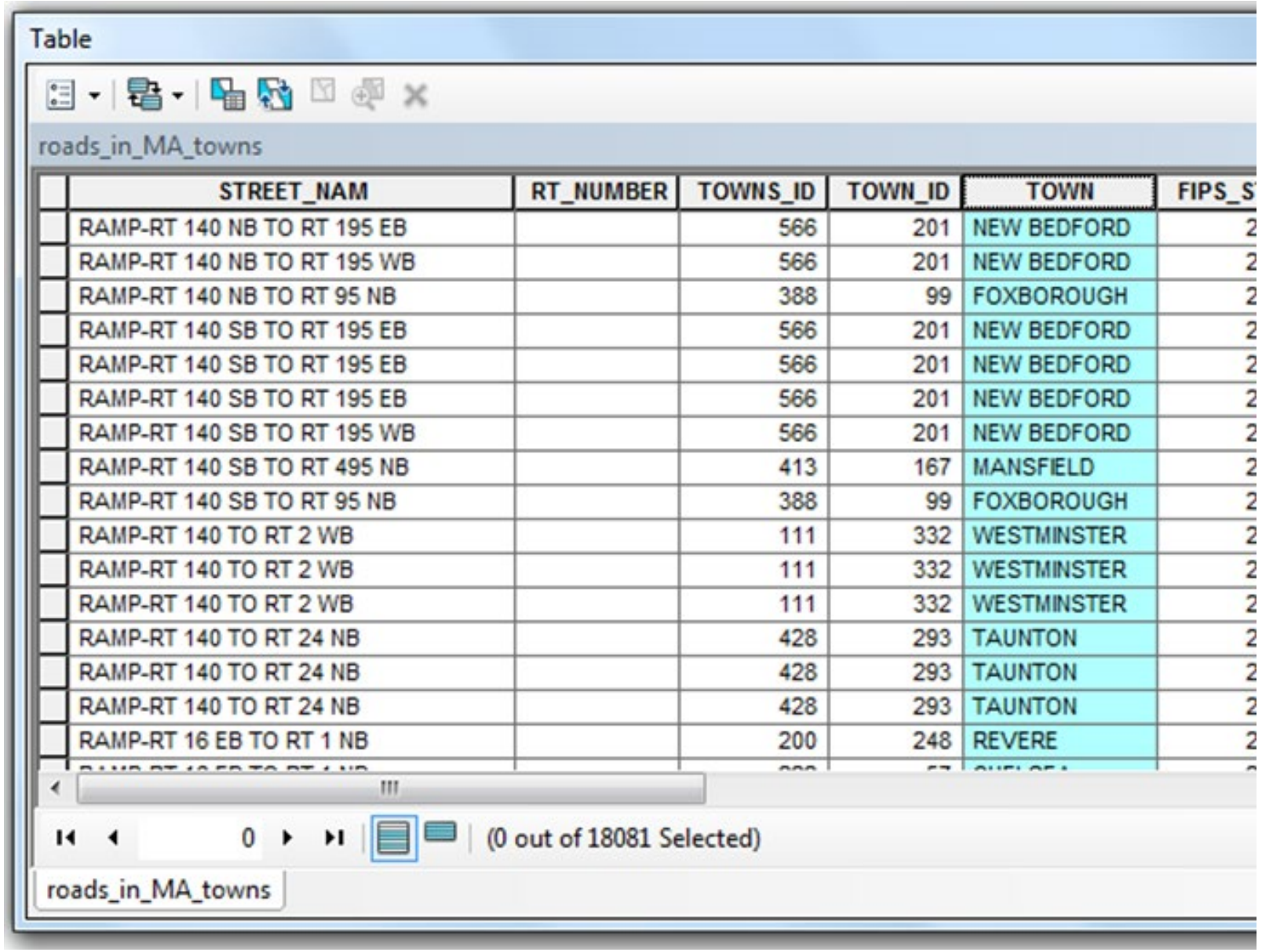


FID	Shape *	OBJECTID	TOWNS_ID	TOWN_ID	TOWN	FIPS_STC
0	Polygon	1	1	259	SALISBURY	250
1	Polygon	2	2	7	AMESBURY	250
2	Polygon	3	3	180	MERRIMAC	250
3	Polygon	4	4	206	NEWBURYPORT	250
4	Polygon	5	5	128	HAVERHILL	250
5	Polygon	6	6	324	WEST NEWBURY	250
6	Polygon	7	7	206	NEWBURYPORT	250
7	Polygon	8	8	206	NEWBURYPORT	250
8	Polygon	9	9	205	NEWBURY	250
9	Polygon	10	10	206	NEWBURYPORT	250
10	Polygon	11	11	206	NEWBURYPORT	250
11	Polygon	12	12	205	NEWBURY	250
12	Polygon	13	13	205	NEWBURY	250
13	Polygon	14	14	181	METHUEN	250
14	Polygon	15	15	116	GROVELAND	250
15	Polygon	16	16	205	NEWBURY	250

Road Segments in Towns

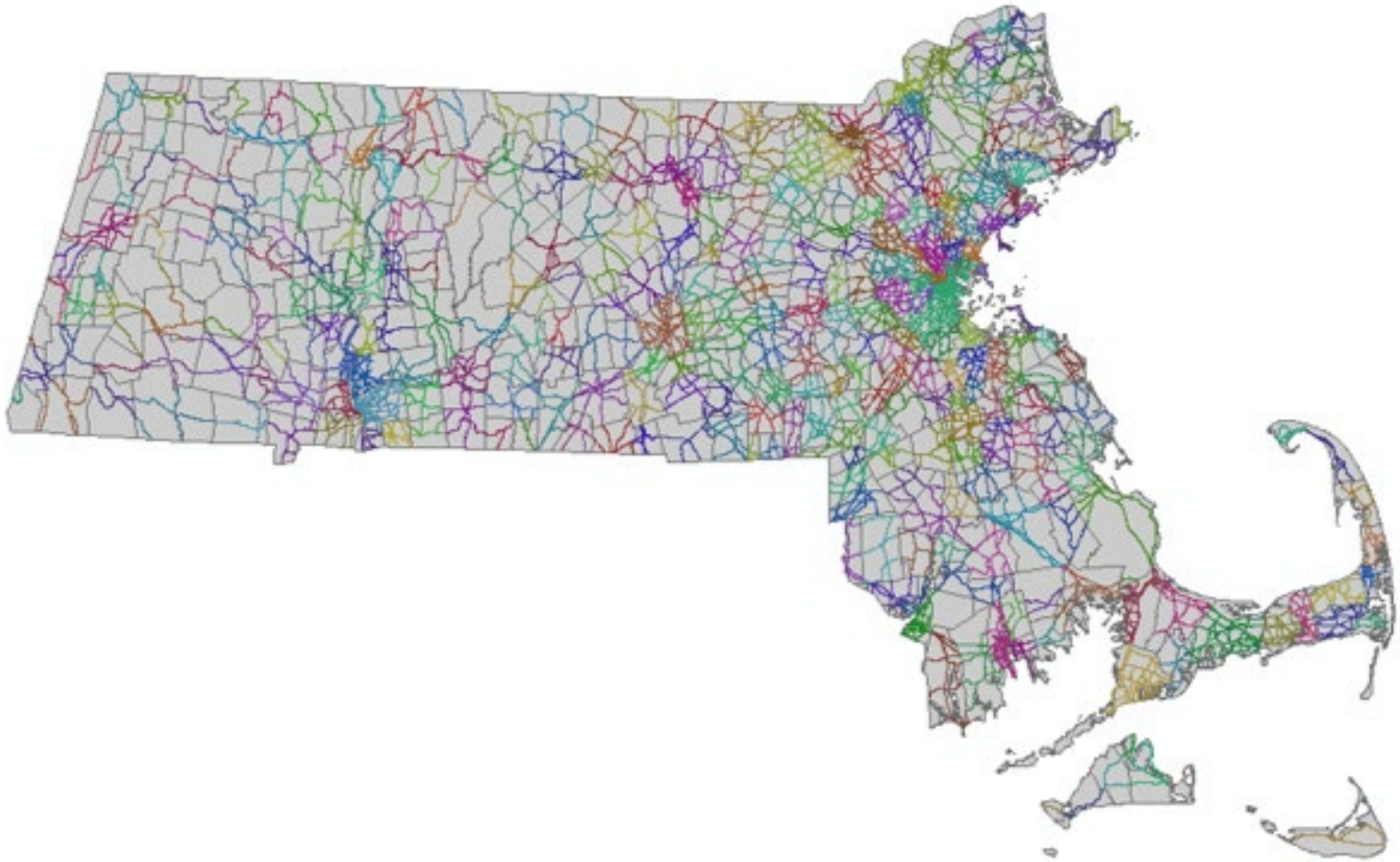
Attribute table **after** intersection

- There are 18081 features.
- What does a feature represent?



Road segments within towns

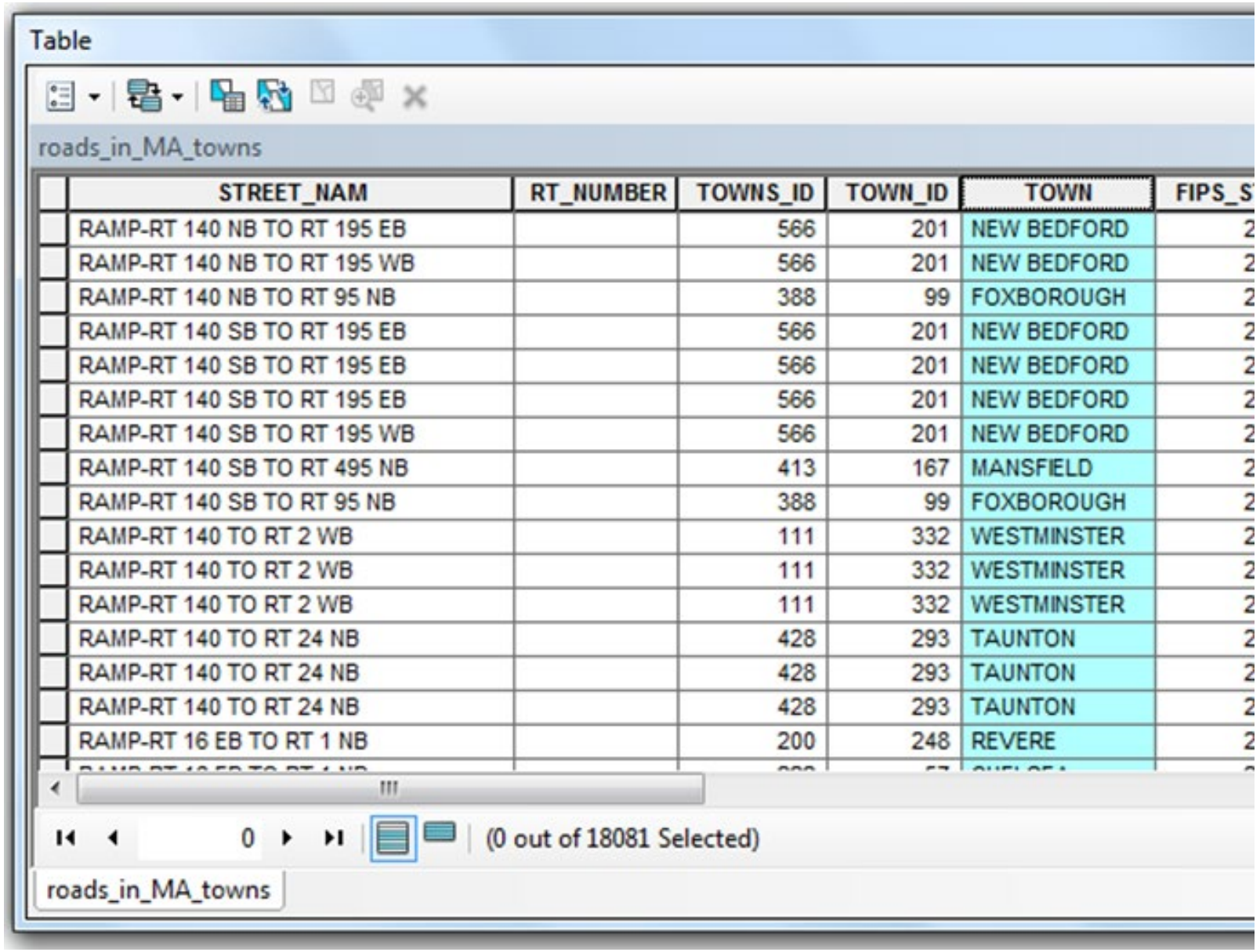
- Segments symbolized by town



What is the total length of roads in each town in MA?

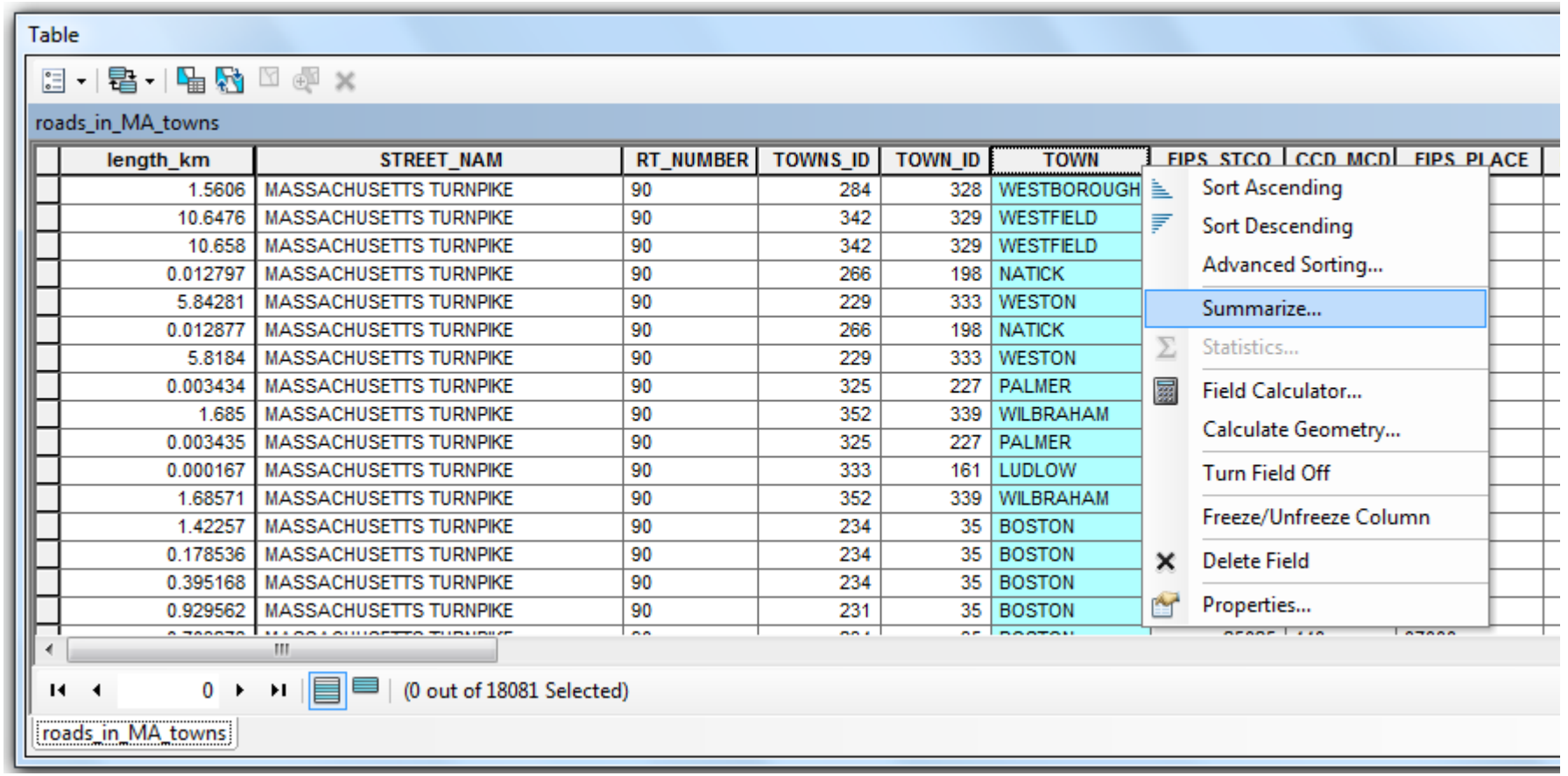
Our original question

- We could use brute force to manually select features that match each of the 631 towns, or…



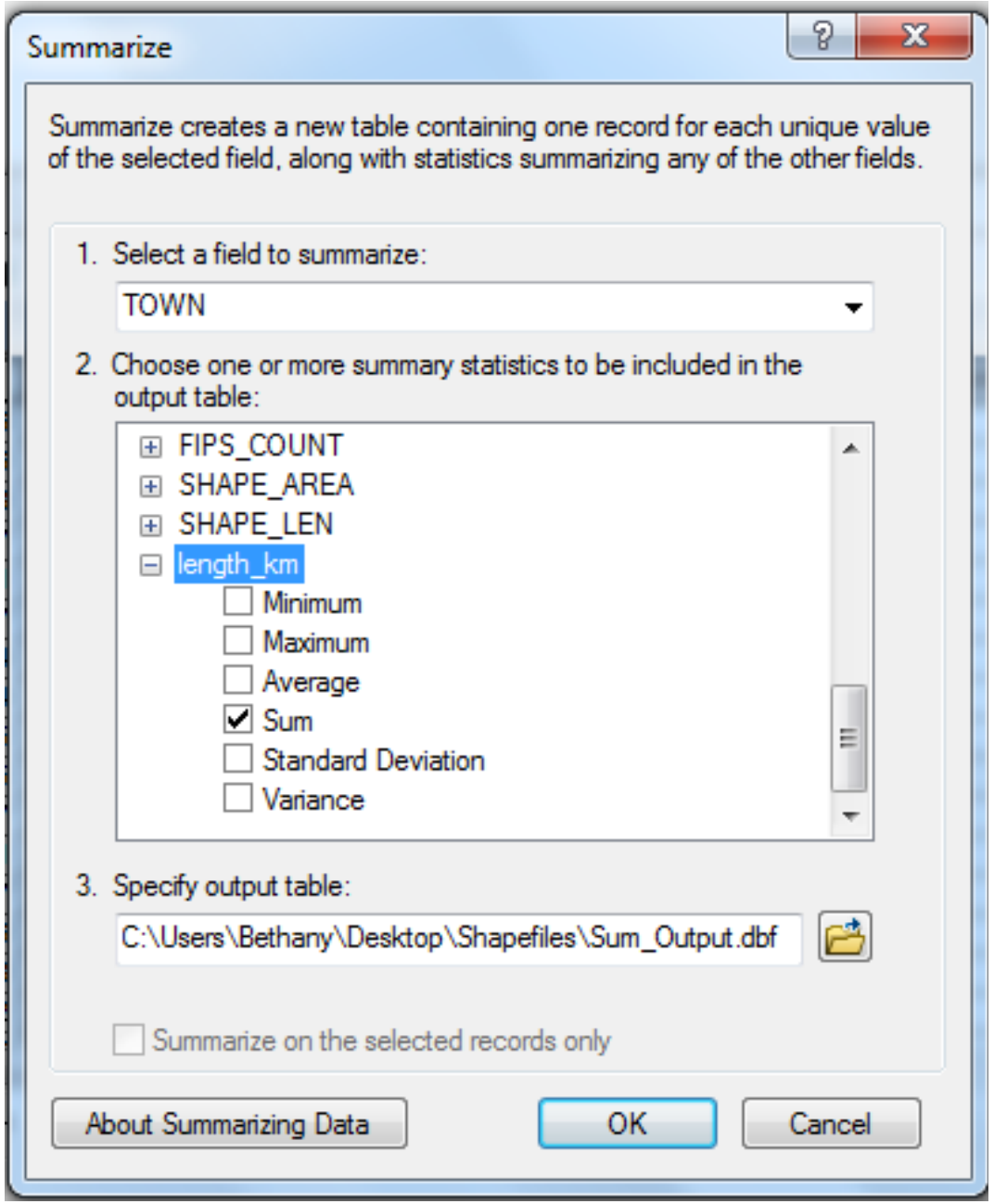
Why summarize is awesome!

Why is the summarize tool awesome?



Aggregation

- Summarize will count features, aggregated by unique values
- It will also perform calculations like total length, area, etc!



Aggregation

Summarize creates a table with:

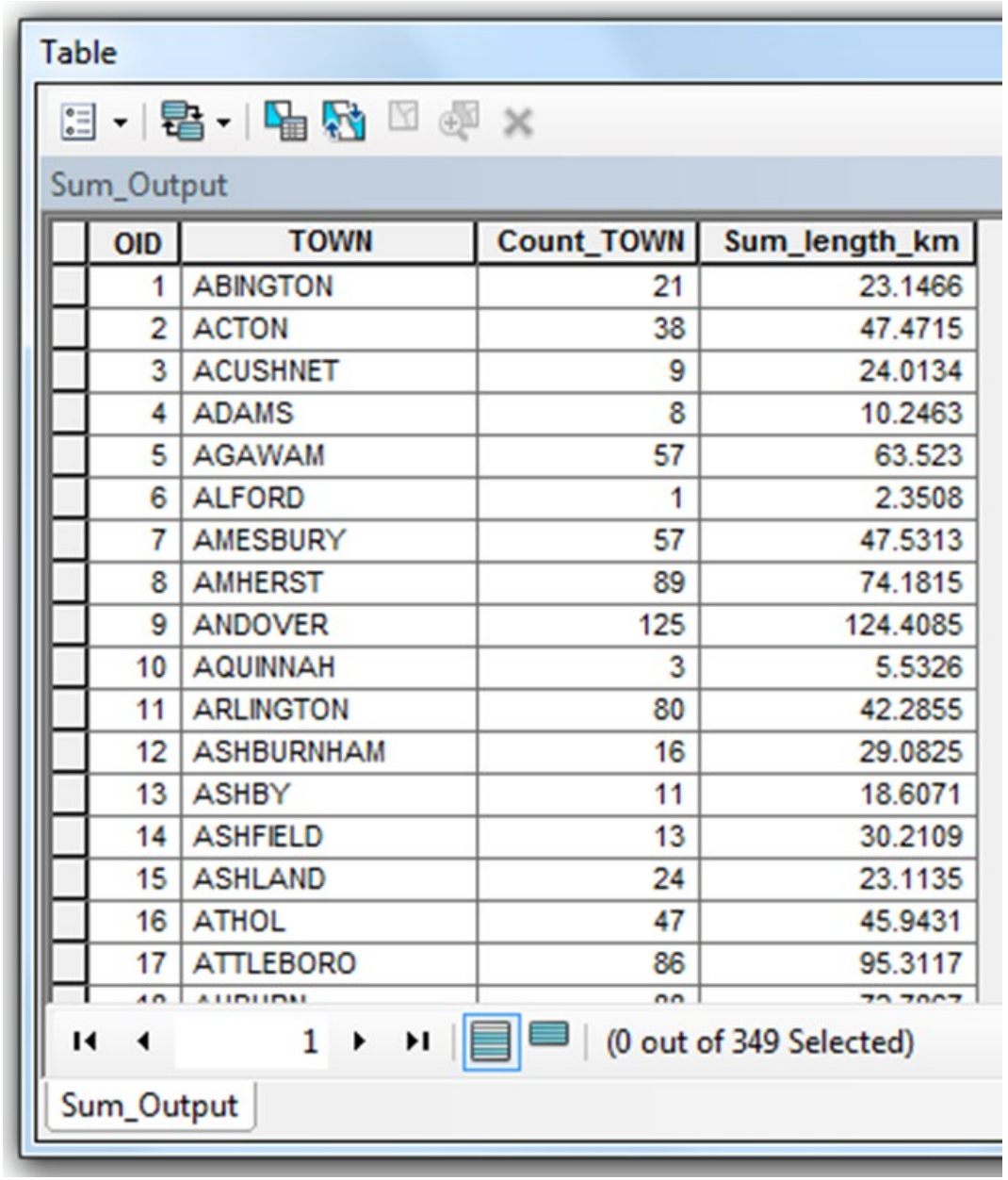
Count_TOWN:

- Total number of major road segments in that town.

Sum_length_km:

- Sum of the lengths of all major roads in that town.

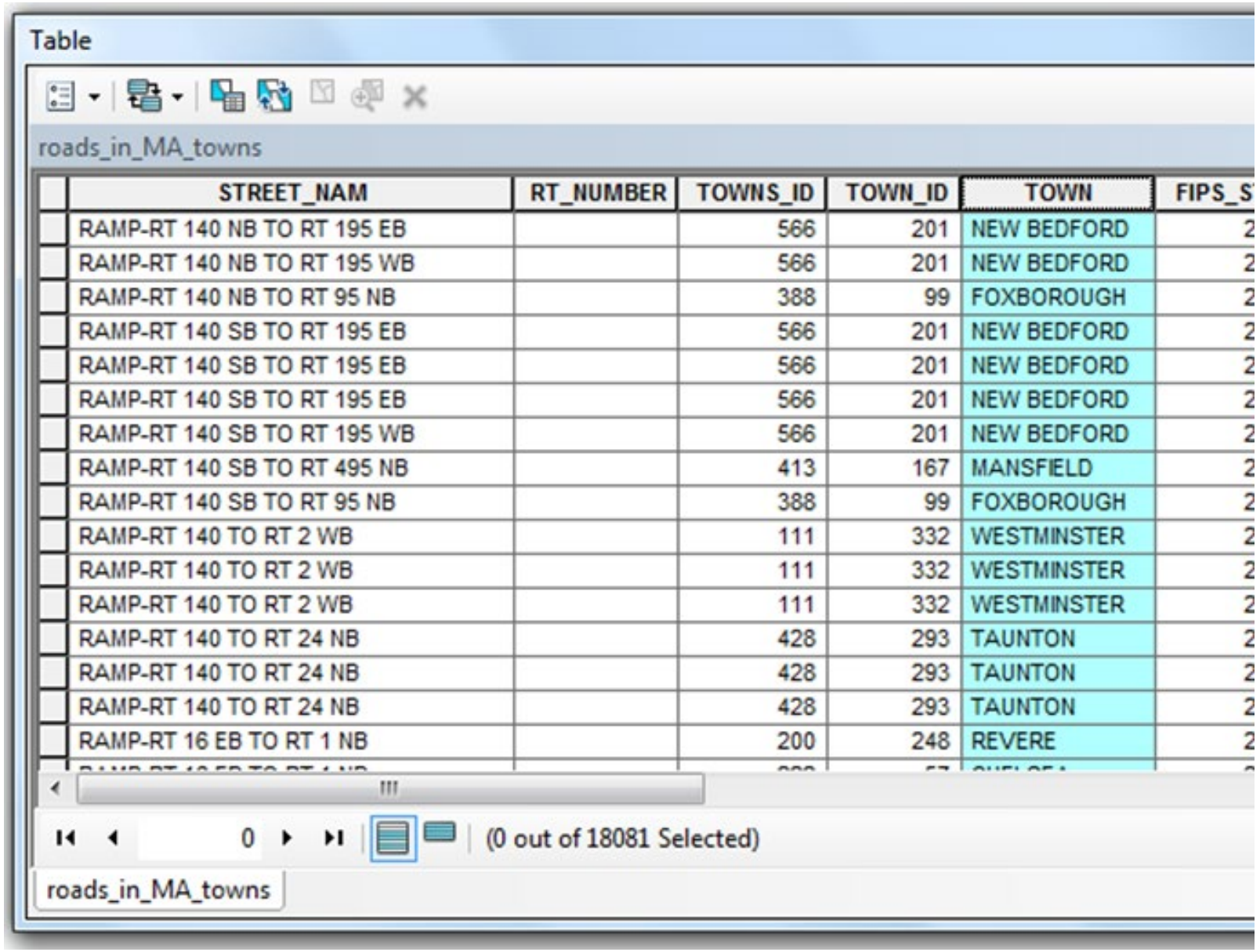
Are we finished?



What is the total length of roads in each town in MA?

We now have a total road length for each town…

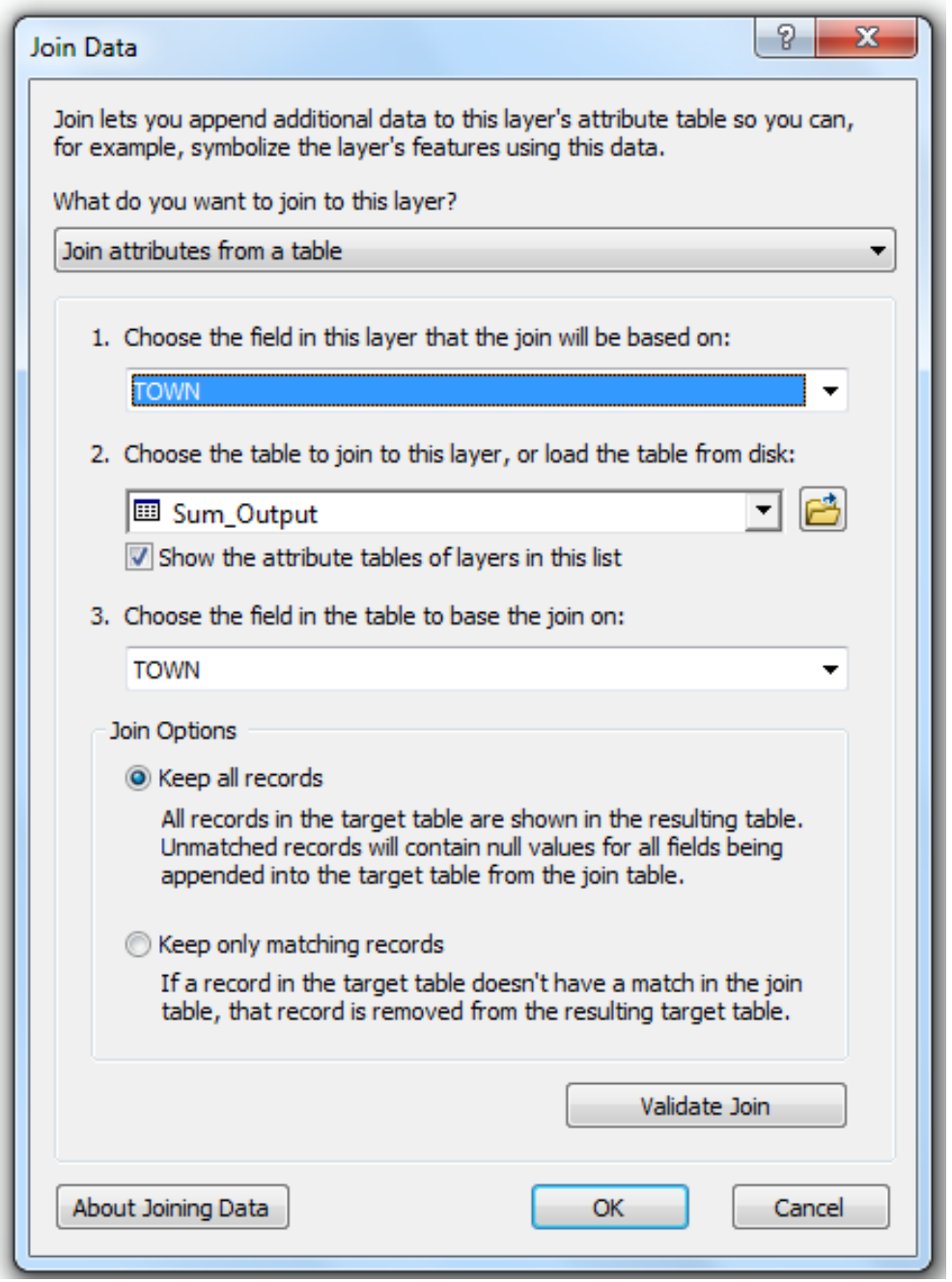
how could we **join** these measurements to our towns attribute table?



Join!

Join the summary table back to the towns polygon (both have the common attribute of TOWN)

This will bring the attribute of total road length into your polygon shapefile of roads



What is the name for this kind of map?