# GPS and Grid to Ground

by Steven Jones, PS, CFedS

# Repeatability of Measurements

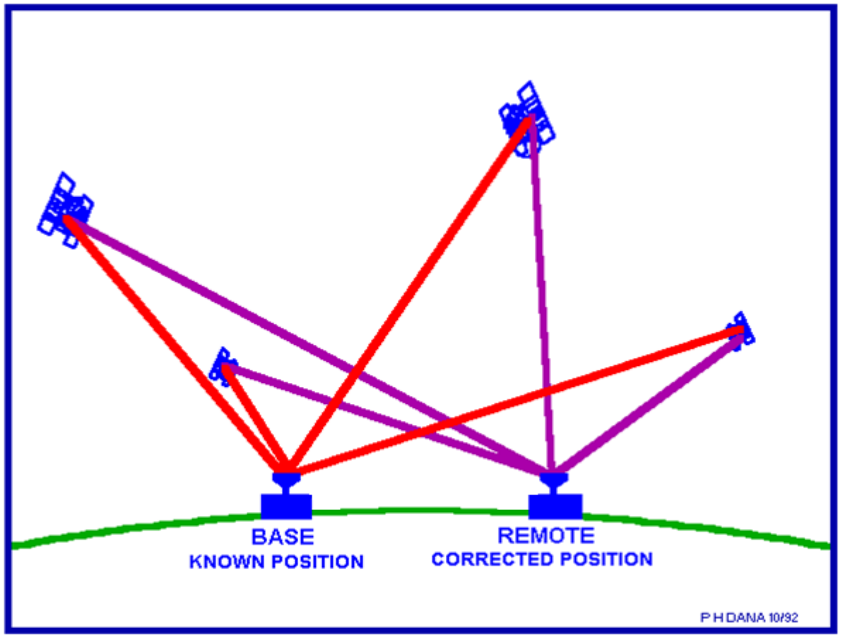
The Surveyor's Goal:

- to be able to easily recreate the position of a particular point on the ground.
- to leave sufficient evidence that another surveyor can recreate that same point

# Components of a GPS Position

- Measurement method – used to obtain latitude and longitude
- Coordinate System – converts latitude and longitude to useable plane coordinates

# Post Processed Static & OPUS





***Uses***

- Control surveys that cover large areas
- Surveys in areas where it is difficult to maintain radio communication

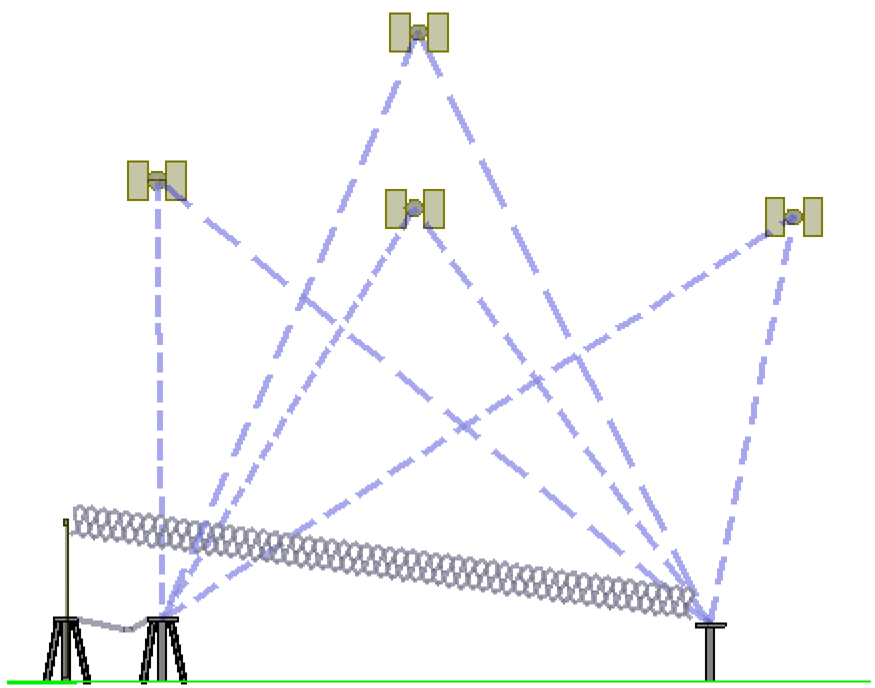
***Advantages***

- The most precise method
- Data can be manipulated more than with other methods
- Can be used in tandem with other methods

***Disadvantages***

- Slow
- Results are not available in real time
- Post processing can reveal that not enough data was collected, and the observation may need to be repeated
- Cannot be used for stakeout
- OPUS results can vary

# Real Time Kinematic
## with a base station



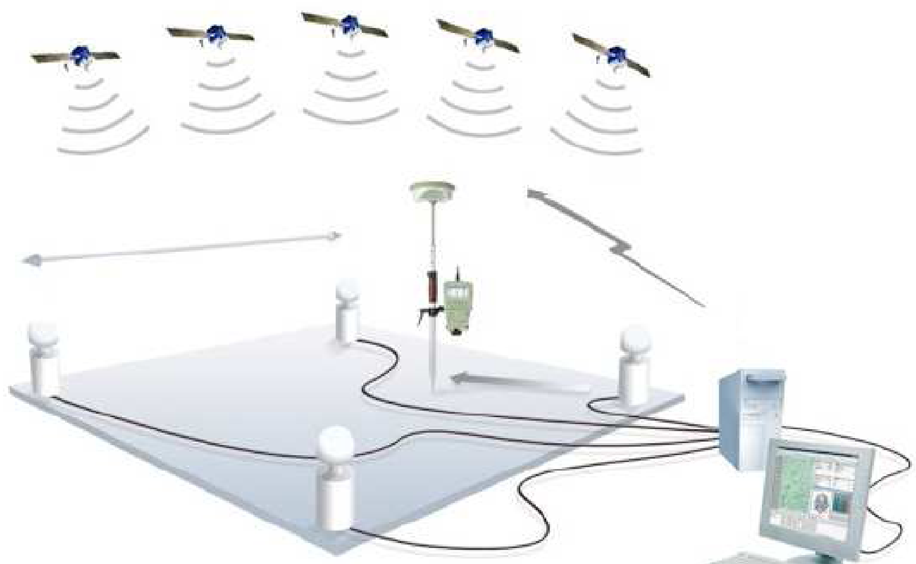
*Advantages*

- Results available in real time
- Accurate enough for most survey applications
- Better vertical accuracy than with a Real Time Network
- Fast

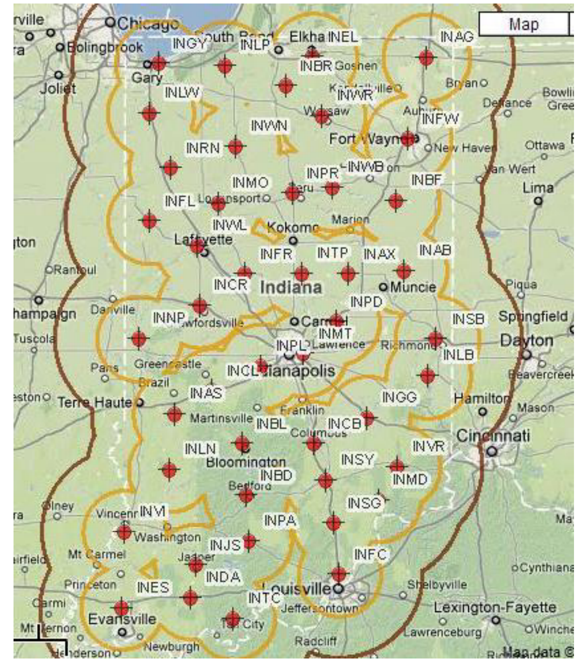
*Disadvantages*

- Less accurate than static
- Requires constant radio communication from a base station
- May not produce globally accurate coordinates

# Real Time Networks



Leica Geosystems Americas, Smartnet Portal




Advantages

- Similar to those of RTK
- Better global accuracy

Disadvantages

- Reliance on outside entities
- Weaker vertical solution than with a base station
- Requires cellular service
- Results can vary based on the correction type

# Real Time Network Corrections Types

MAX - master-auxiliary corrections , optimal solution

iMAX – individualized master-auxiliary corrections , for use with older GPS units

VRS – virtual reference station (similar to iMAX but does not produce vector data from a fixed base station)

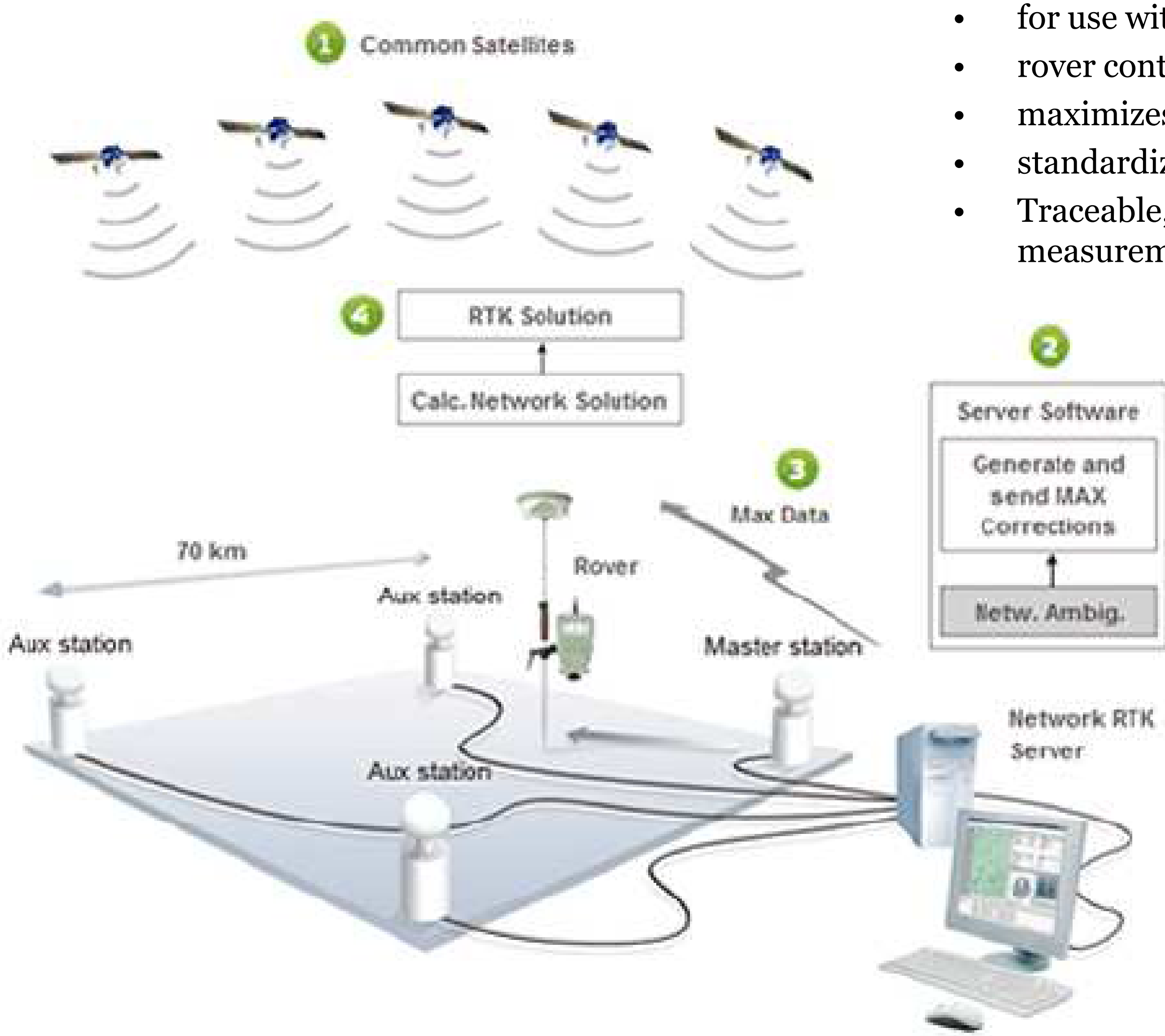
NEAREST – allows the unit to select a single base station WARNING: receiver may switch base stations without notifying the user

Selecting an individual base station manually - you need to know where you are at in the network

# MAX

master-auxiliary corrections

- for use with newer GPS units
- rover controlled solution
- maximizes usage of satellite data
- standardized algorithms
- Traceable, repeatable measurements

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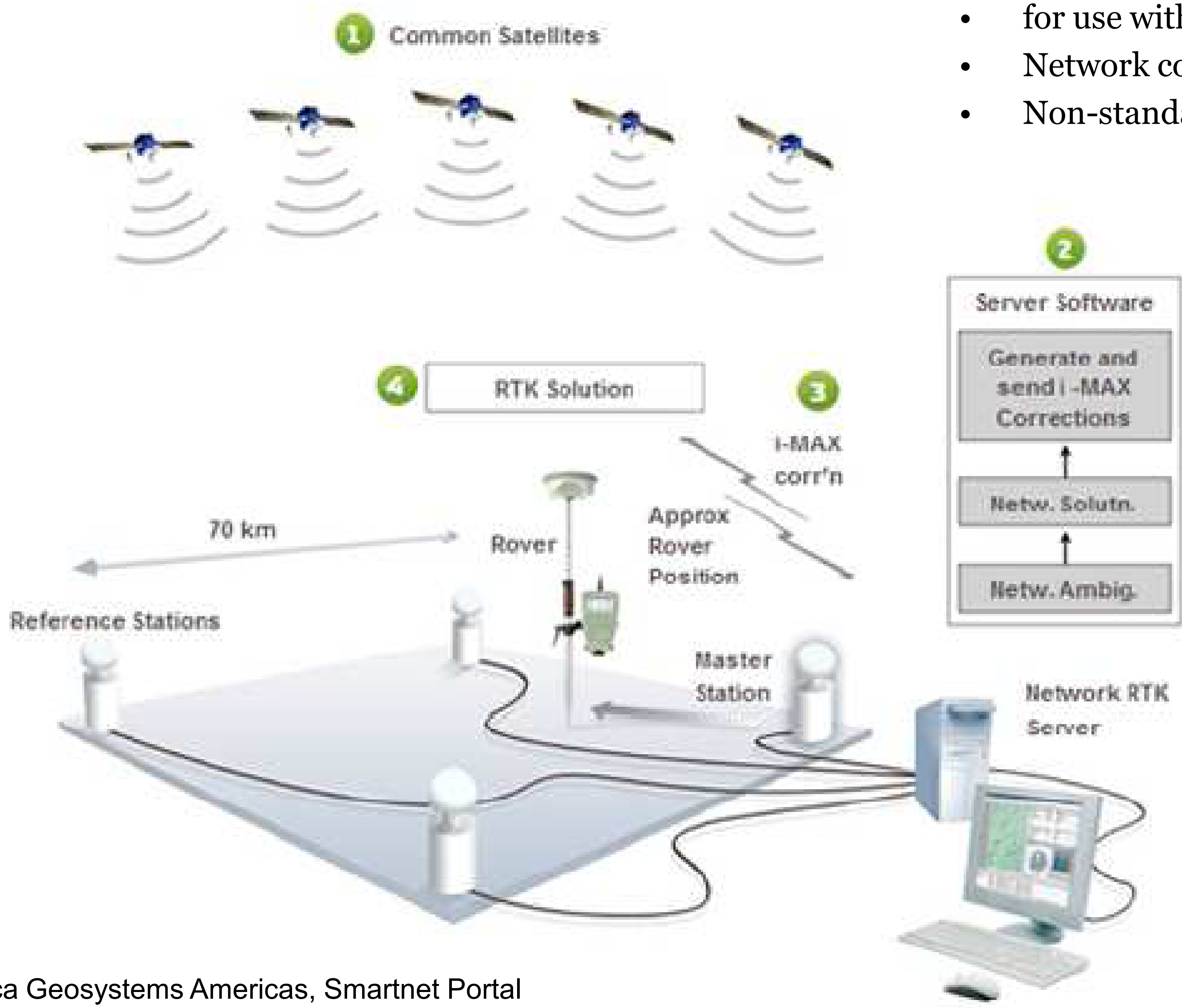
# iMAX

individualized master-auxiliary corrections

- for use with older GPS units
- Network controlled solution
- Non-standardized algorithms

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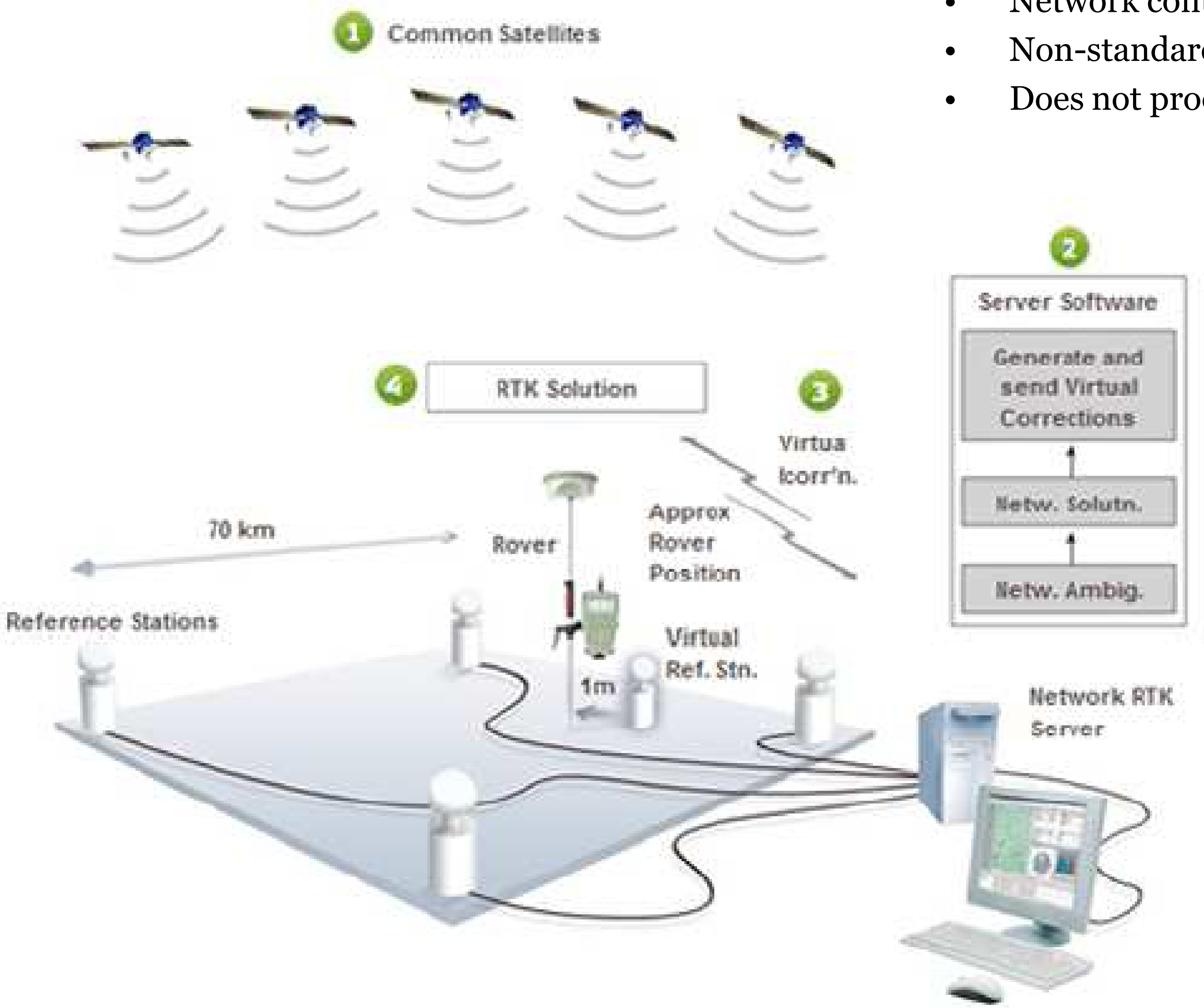
# VRS-Virtual Reference Station

- Network controlled solution
- Non-standardized algorithms
- Does not produce vector data

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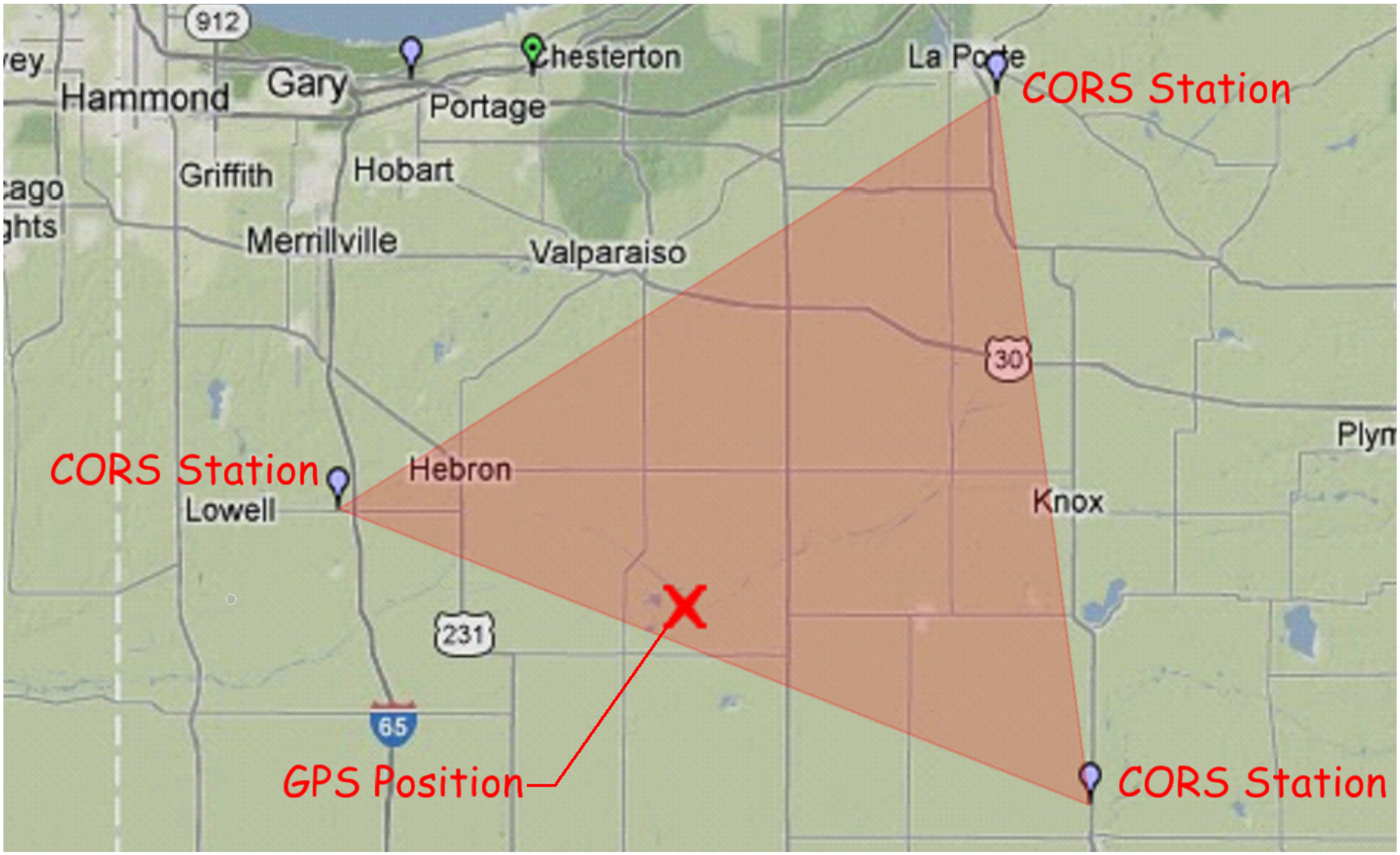
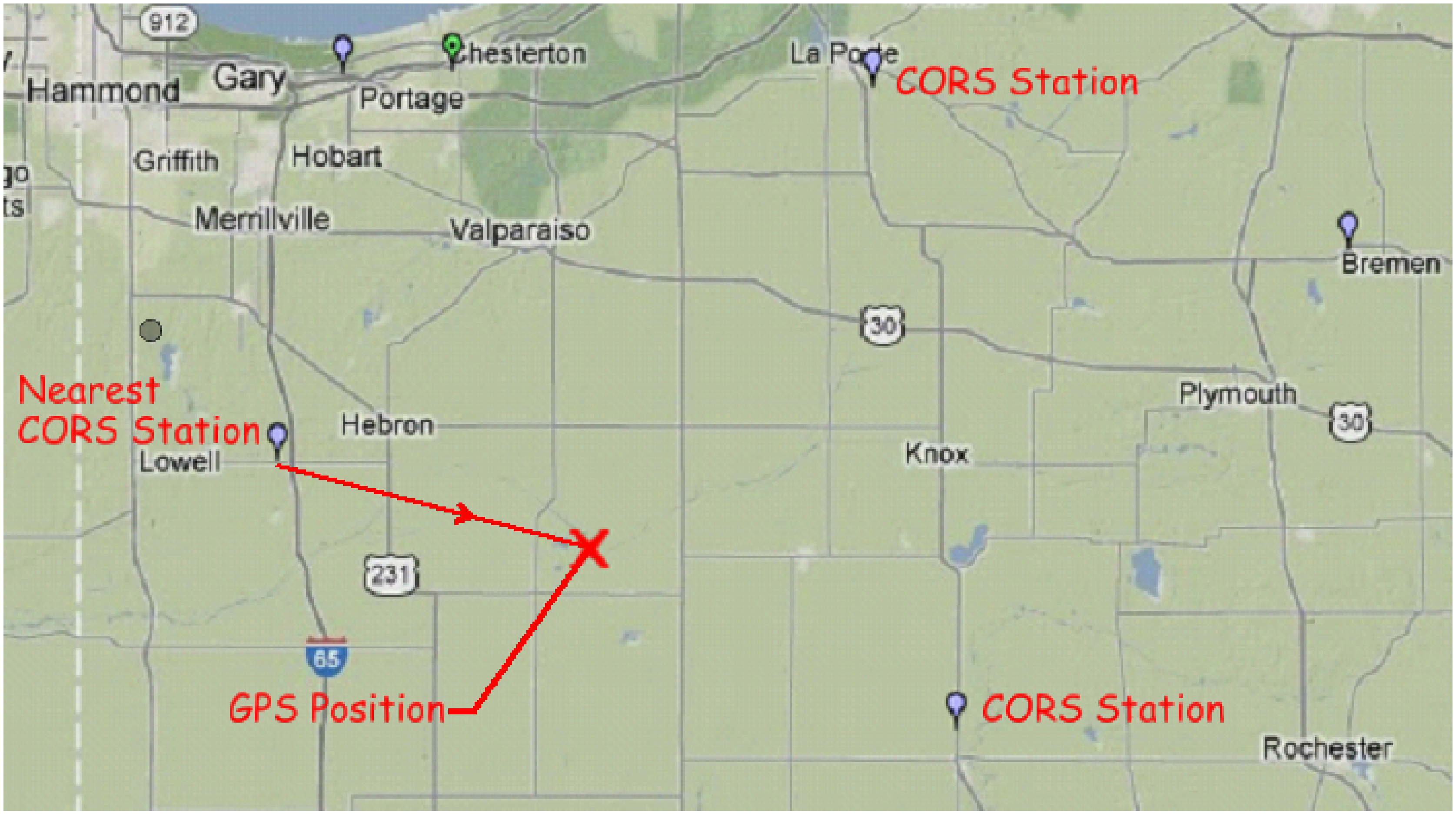
# Weighted Corrections
(MAX, iMAX, VRS)



# Single Baseline Correction
(Nearest, choosing a base)



# Passive vs. Active Control


Passive – monuments

- Traditionally accepted method
- Tangible
- Dependant on the existence of a benchmark network
- Monuments can be expensive to place & maintain
- Monuments have varying accuracies

Active – CORS

- Easily utilized with GPS
- Does not require physical monuments near the project
- More cost effective to maintain
- Higher accuracies
- Impossible to reproduce without GPS
- Subject to GPS sources of error

GPS *always* works in global coordinates

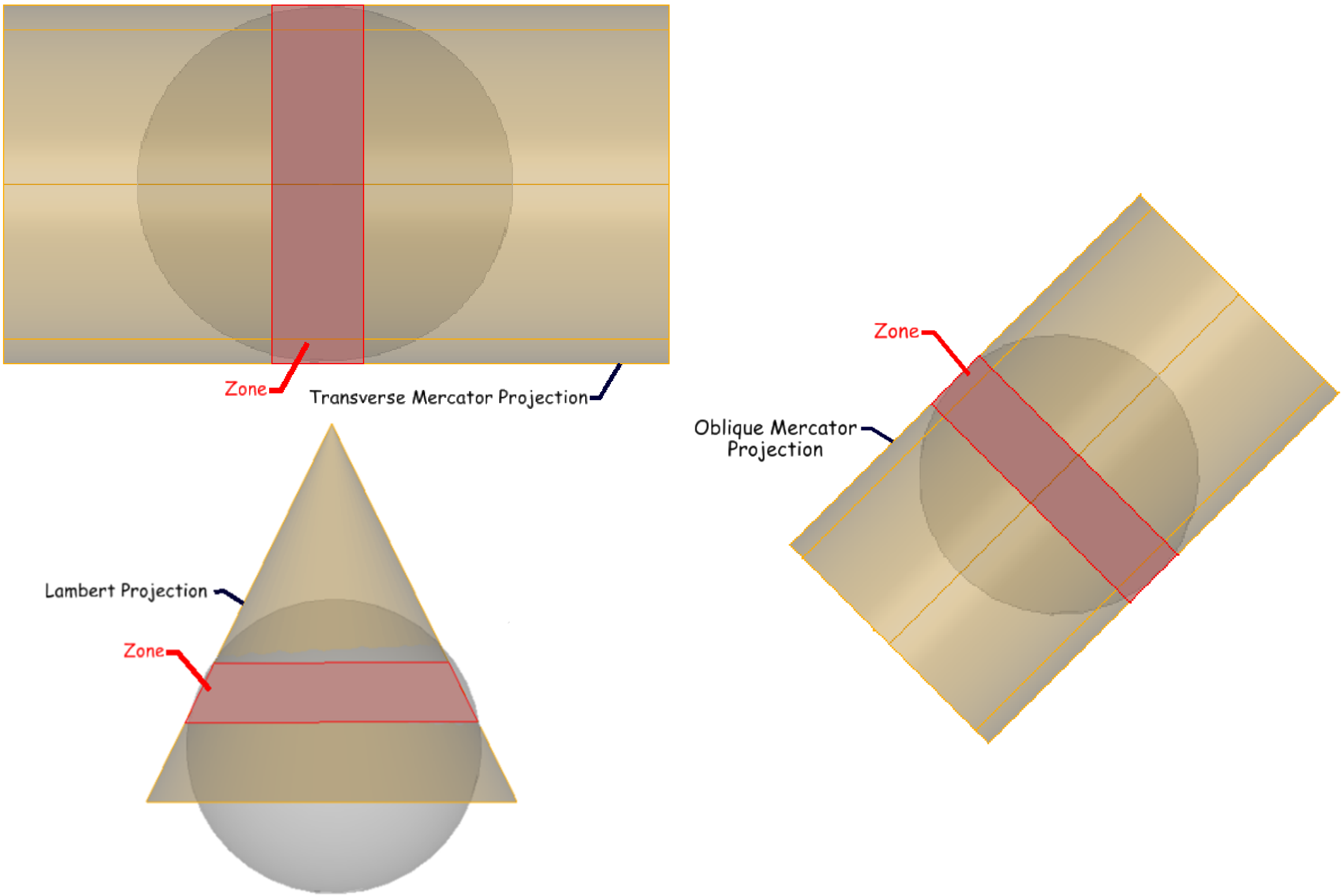
# Components of a Coordinate System

Ellipsoid – mathematical (best fit) model of the earth at sea level

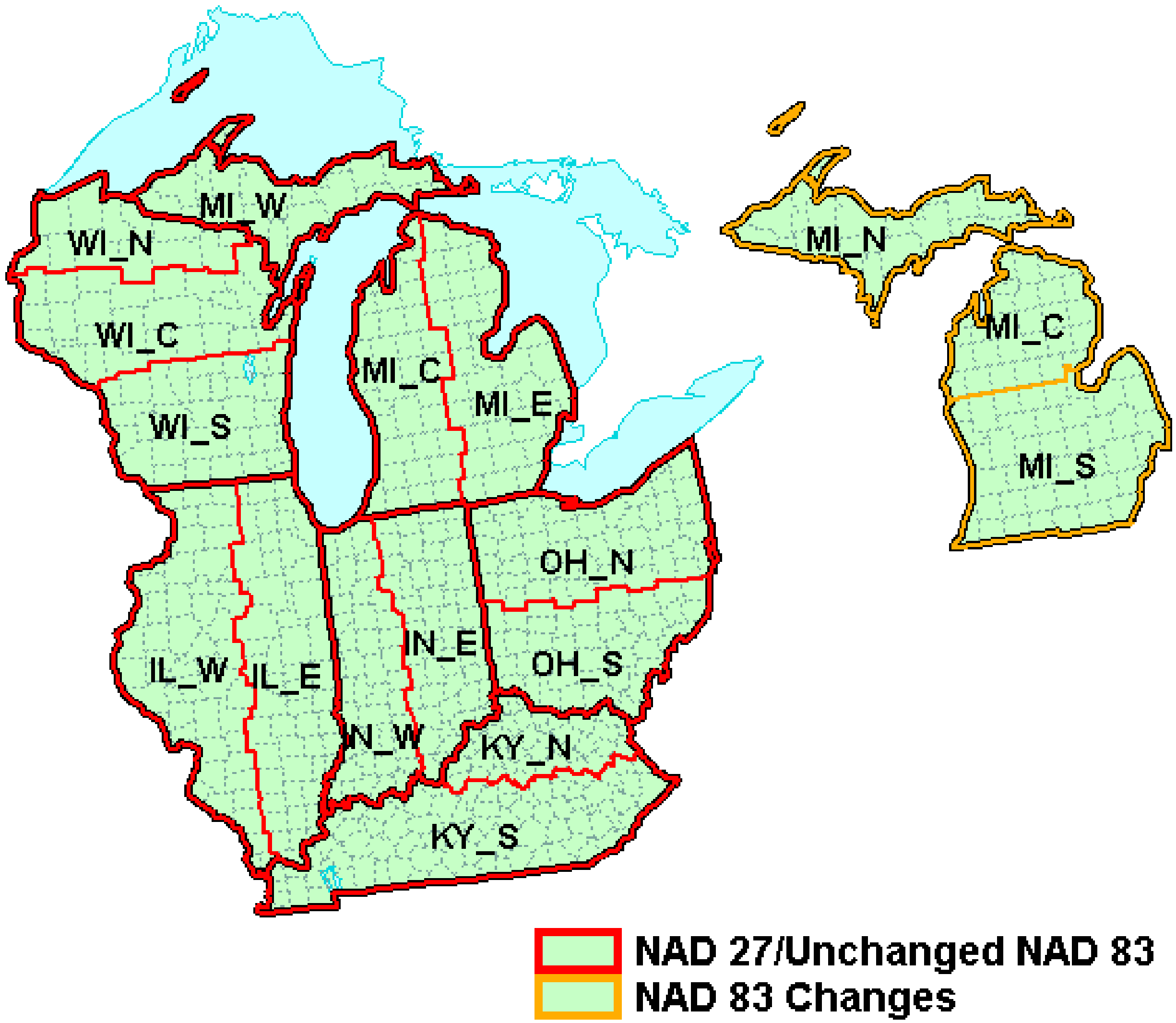
Projection system – method of unrolling the curved surface of the earth to a flat plane

Geoid Model – correction from the best fit sea level to actual sea level

# 3 Most Typical Projection Systems



# State Plane Systems



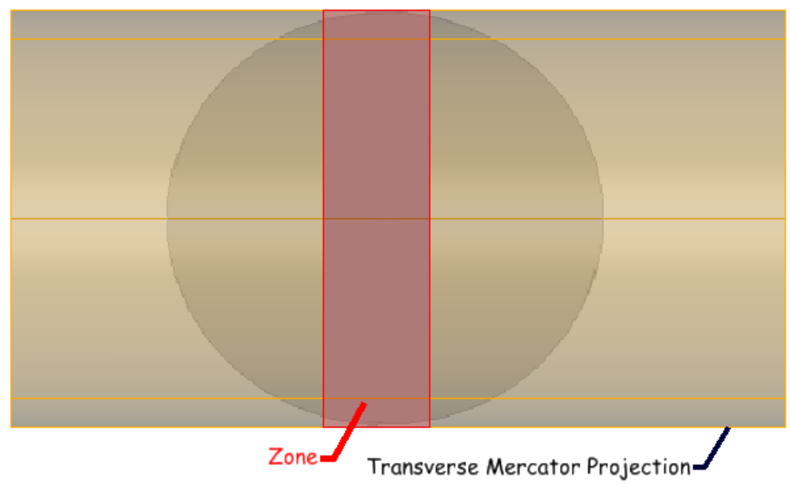

http://www.xmswiki.com/wiki/Mideast_State_Plane

# Extending Coordinate Systems

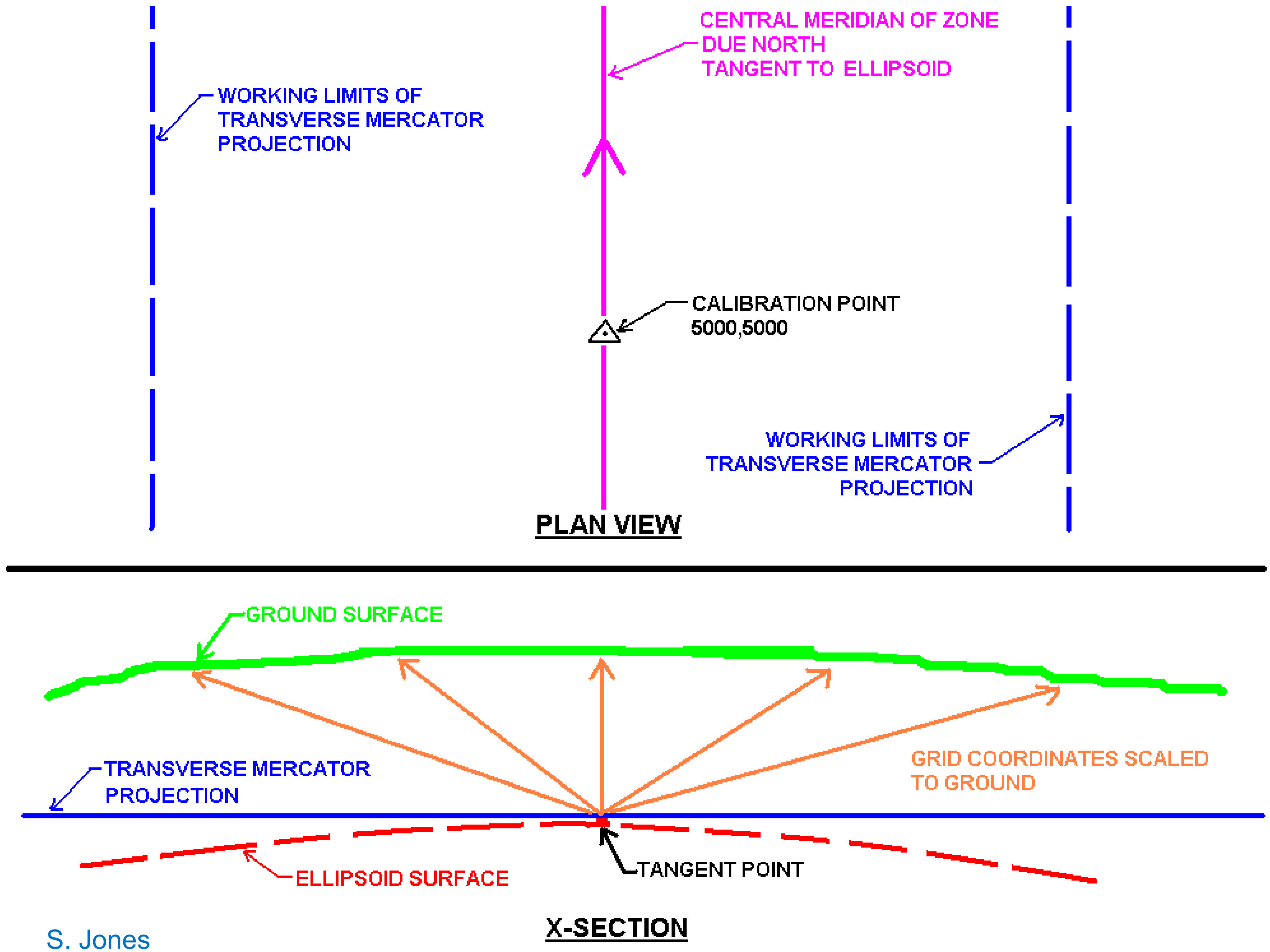

Neil Palmer & Associates

Guardian Pipeline

- Since IL East zone utilizes a Transverse Mercator projection, it was able to be extended north to Green Bay with minimal distortion



# 1-Point Horizontal Calibration

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# 1-point Horizontal

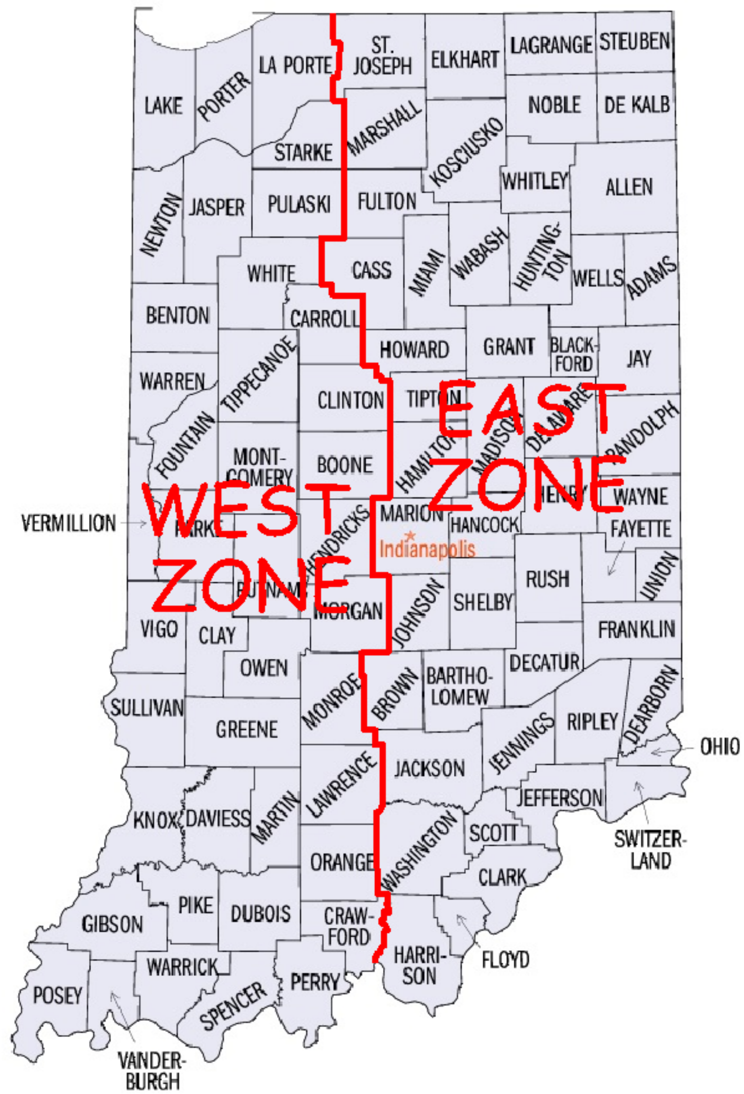
Advantages

- Simple process
- Orientates the site nearly to true north

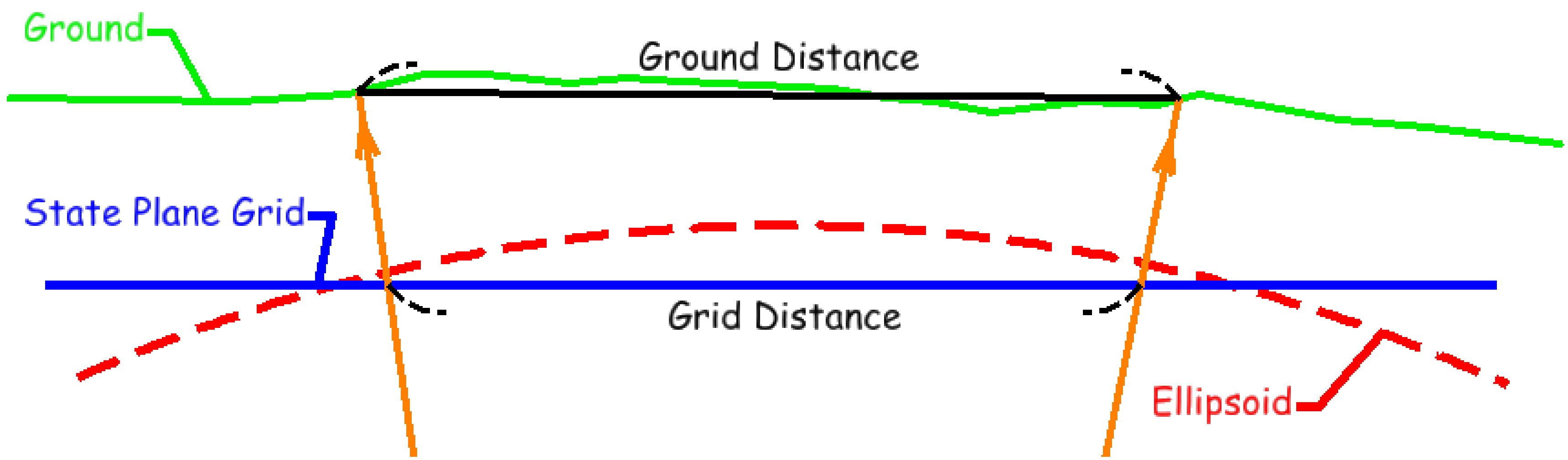
Disadvantages

- No fixed basis of bearings
- Accuracy is degraded on large sites
- Accuracy is degraded on sites with massive elevation change
- More difficult to reproduce

# Indiana State Plane Coordinates



# Grid vs. Ground

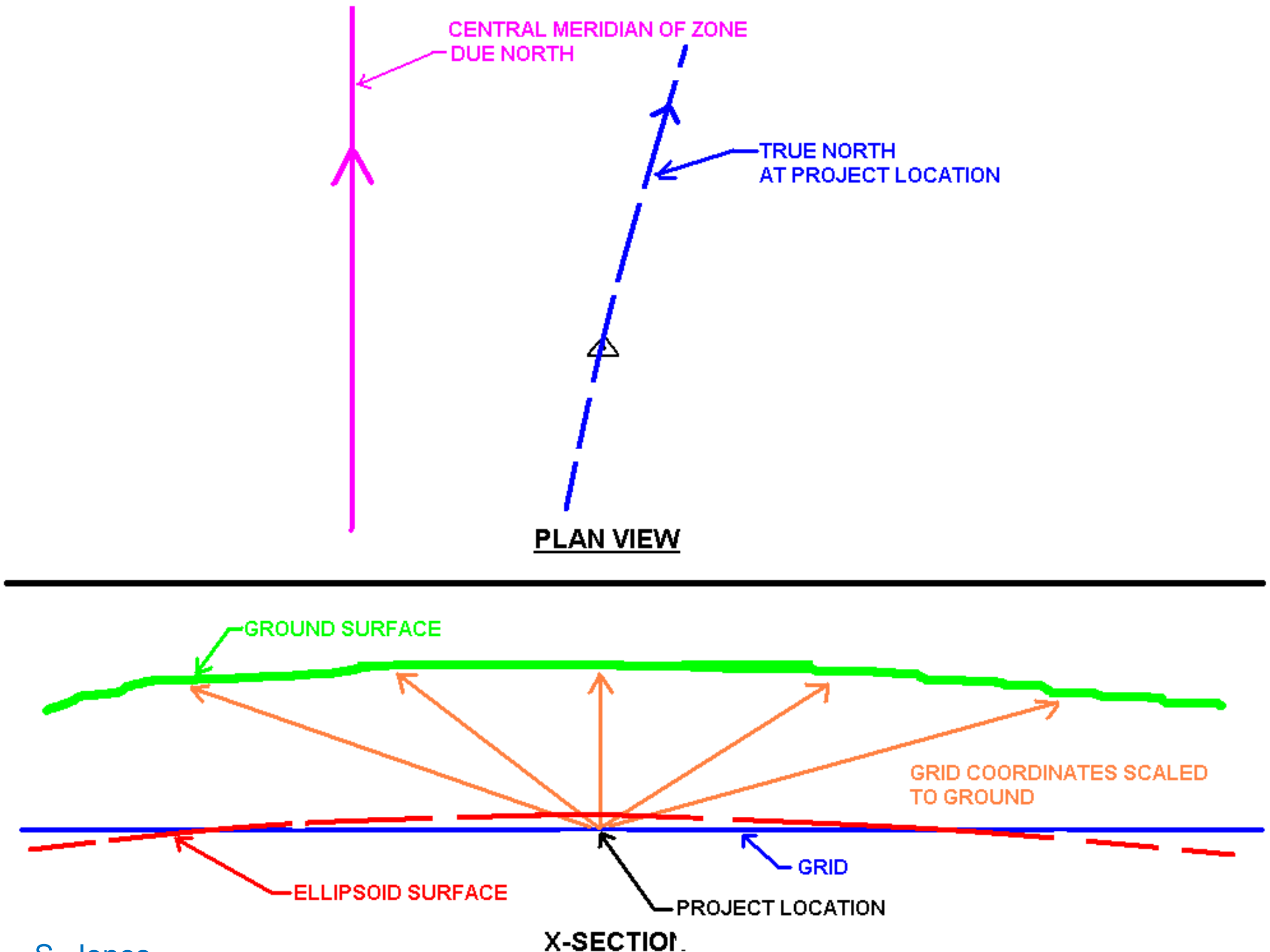



The distortion between a grid distance and a ground distance is represented by the Combined Scale Factor.

# Methods of dealing with Grid to Ground Distortions

- Scale coordinates about local point and truncate coordinate values
- Scale coordinates about local point without truncating coordinate values
- Scale coordinates about 0,0 with truncation
- Perform all mapping on the grid

# State Plane Coordinates scaled to ground

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# State Plane Coordinates Scaled to Ground about a Local Point
## with coordinate truncation

***Advantages***

- Fixed basis of bearings
- Small coordinate values
- Can be easily reproduced, if the scale point exists
- Distances will measure correctly on the ground
- Same basis of bearings as GIS data and aerial photos
- Compatible with Trimble & Topcon products
- INDOT preferred method

***Disadvantages***

- Distortions increase as you move away from the project location.
- GIS data requires translation before use
- The exact same point in two adjacent projects will have different coordinate values
- North of the state plane zone may vary greatly from true north at the site. This variance must be accounted for when restoring lost PLSS corners by methods other than single proportionate measure, grant boundary adjustment, and meander line adjustment.

# State Plane Coordinates Scaled to Ground about a Local Point without coordinate truncation

***Advantages***

- Fixed basis of bearings
- Can be easily reproduced, if the scale point exists
- Distances will measure correctly on the ground
- GIS data and aerial photos do not require any rotation or translation
- Compatible with Trimble & Topcon products
- Data integrates easily into GIS

***Disadvantages***

- Coordinates can be easily mistaken for grid coordinates
- Large coordinate values
- Distortions increase as you move away from the project location
- The exact same point in two adjacent projects will have different coordinate values
- North of the state plane zone may vary greatly from true north at the site. This variance must be accounted for when restoring lost PLSS corners by methods other than single proportionate measure, grant boundary adjustment, and meander line adjustment.

# State Plane Coordinates Scaled to Ground about 0,0
## with coordinate truncation

***Advantages***

- Fixed basis of bearings
- Distances will measure correctly on the ground
- GIS data and aerial photos do not require any rotation
- Compatible with Leica products and Civil 3d
- Calculations can be performed in a spreadsheet

***Disadvantages***

- Coordinates can be easily mistaken for grid coordinates
- Large coordinate values
- Distortions increase as you move away from the project location
- The exact same point in two adjacent projects will have different coordinate values
- North of the state plane zone may vary greatly from true north at the site. This variance must be accounted for when restoring lost PLSS corners by methods other than single proportionate measure, grant boundary adjustment, and meander line adjustment.

# State Plane Grid Coordinates

***Advantages***

- Fixed basis of bearings
- GIS data and aerial photos do not require any rotation or translation
- The exact same point in two adjacent projects will have the same coordinate values
- Compatible with all brands of GPS office and field software, as well as most CAD programs (Civil 3d, Microstation)
- Data integrates easily into GIS

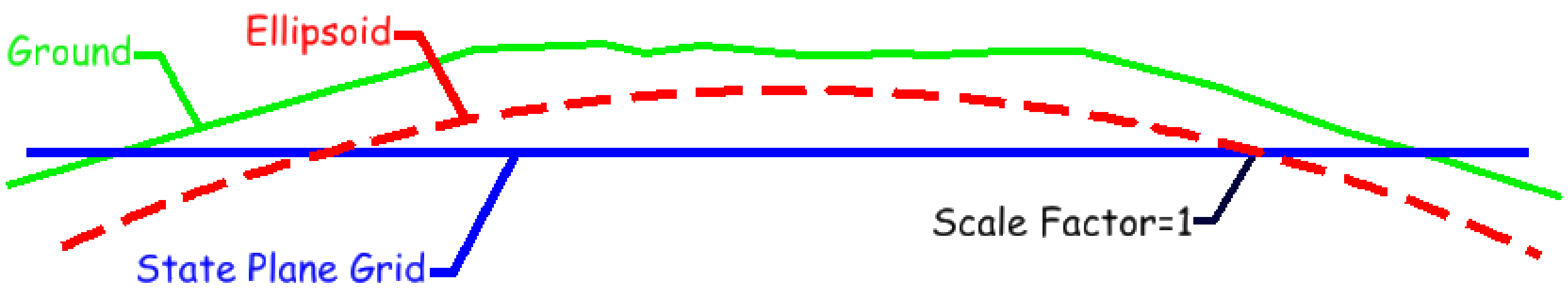
***Disadvantages***

- Distances will not measure correctly on the ground
- Large coordinate values
- North of the state plane zone may vary greatly from true north at the site. This variance must be accounted for when restoring lost PLSS corners by methods other than single proportionate measure, grant boundary adjustment, and meander line adjustment.

# Advantages to using a Published Coordinate System

- Easier use of Aerial orthophotography
- Easier use of Contour/LIDAR Elevation Data
- Import/export Google Earth
- Import/export ESRI shape files
- Data easily integrates with GIS information

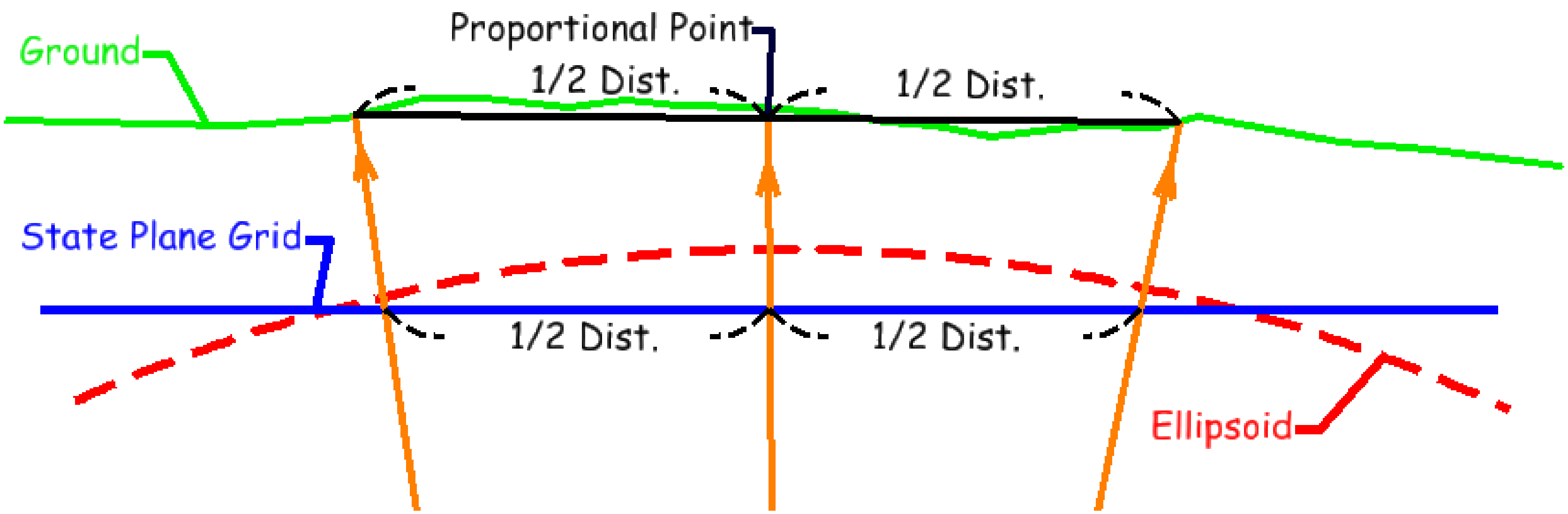
# Scaling to Ground (is it worth it)




- How large is the project
- Where is it in the zone (calculate distortion)
- Site calibration will be needed to use GPS
- GIS data requires translation

# Grid vs. Ground

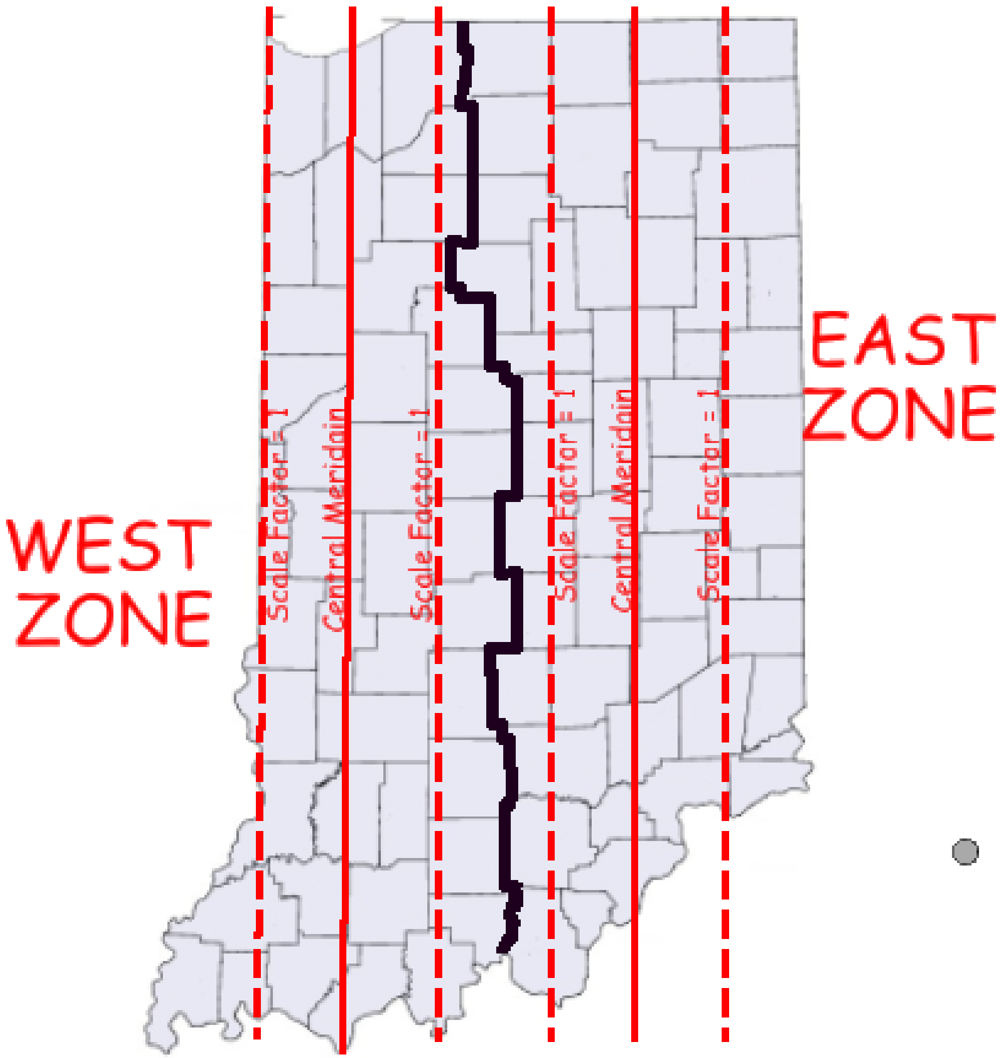
## Sometimes there is no difference




Whether measurements are made on the ground or the grid, proportionate measure will produce the same corner position.

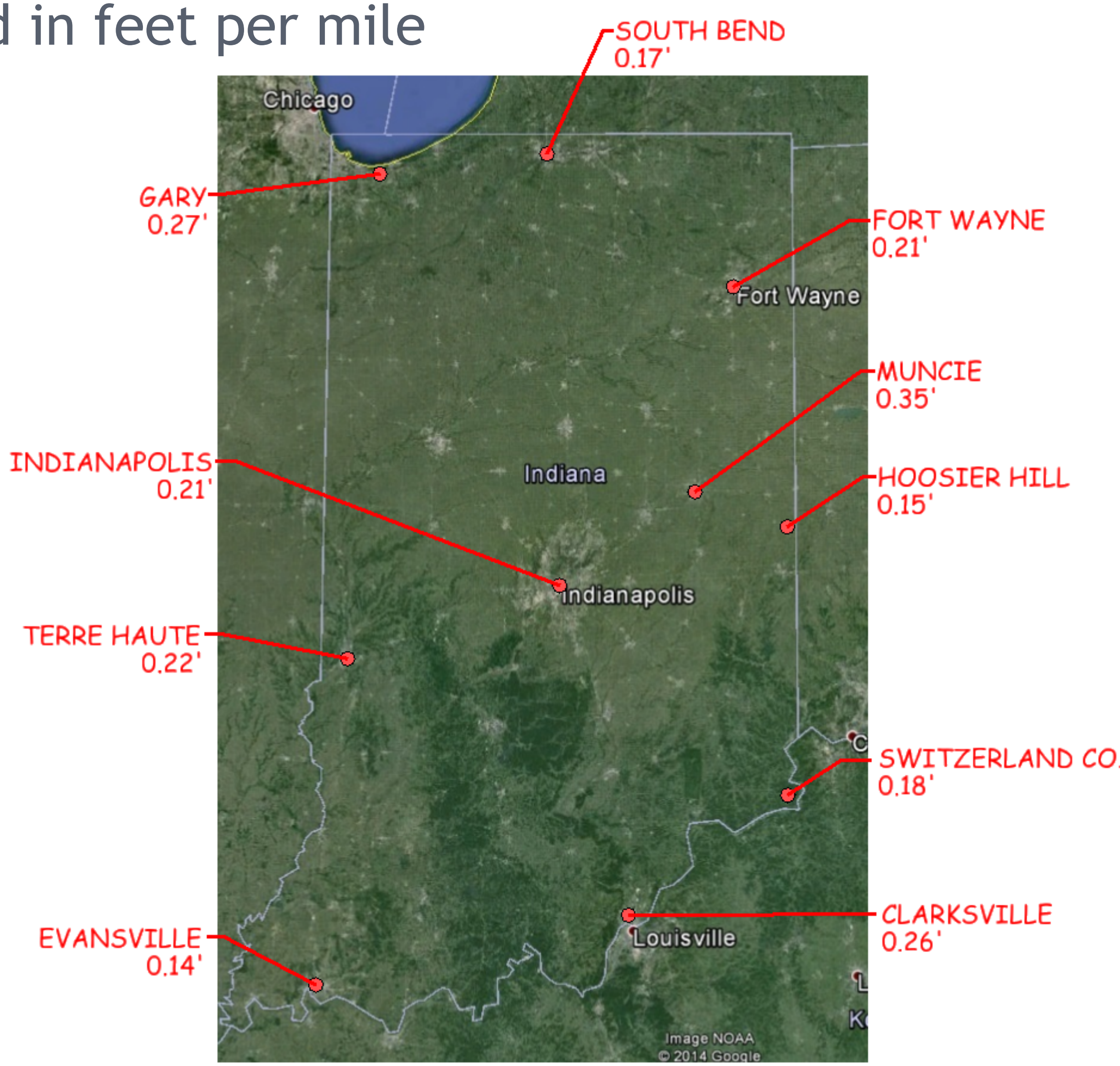
Worst case scenario in Indiana, the area of a 1 acre parcel, if surveyed on grid, would be 3 square feet too small ( less than 0.0001 Ac.)

# Indiana State Plane Zones

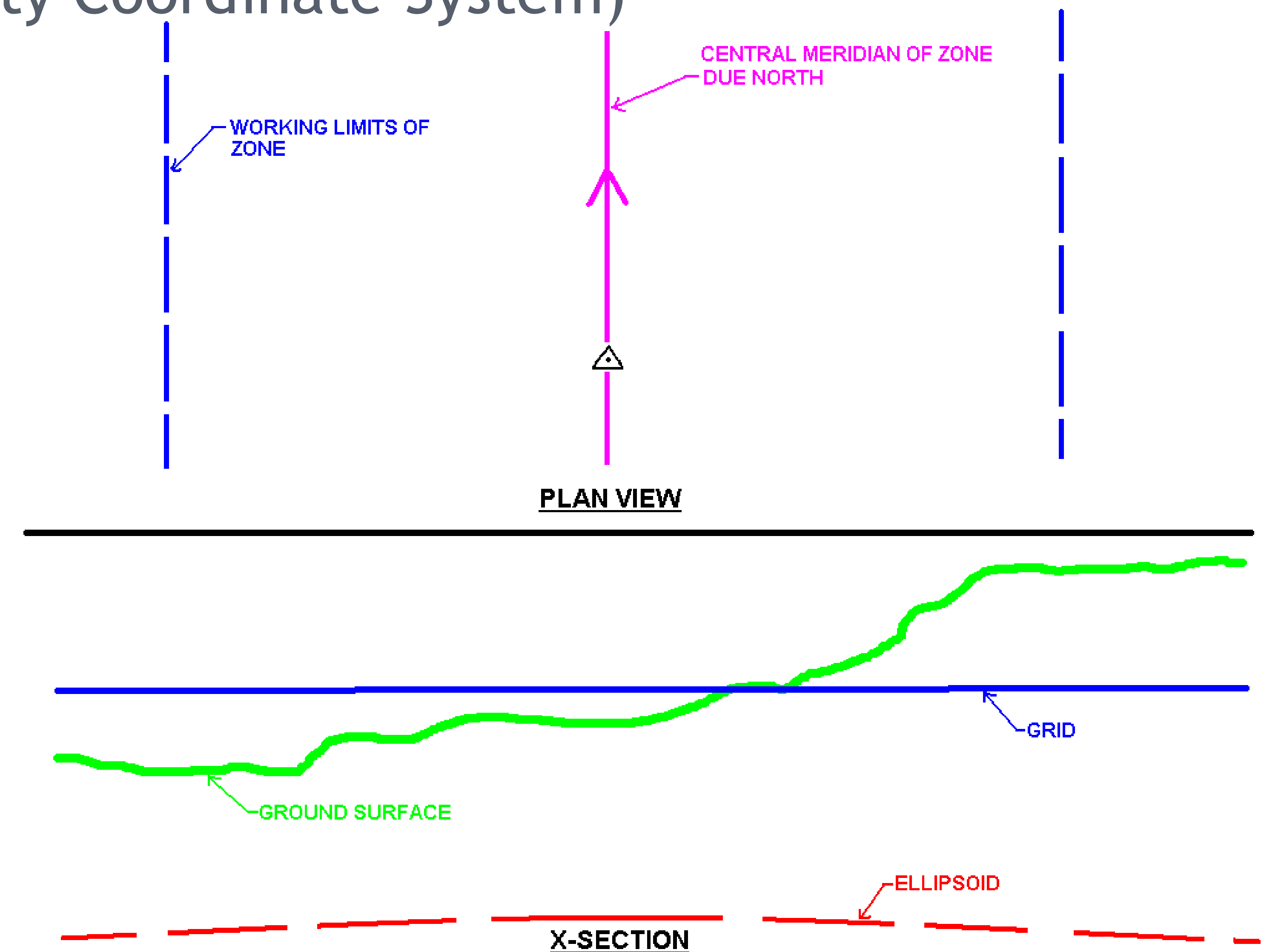


# Grid to Ground Distortions

## Expressed in feet per mile



# Low Distortion Projection Systems
## (County Coordinate System)



# Low Distortion Projection Systems

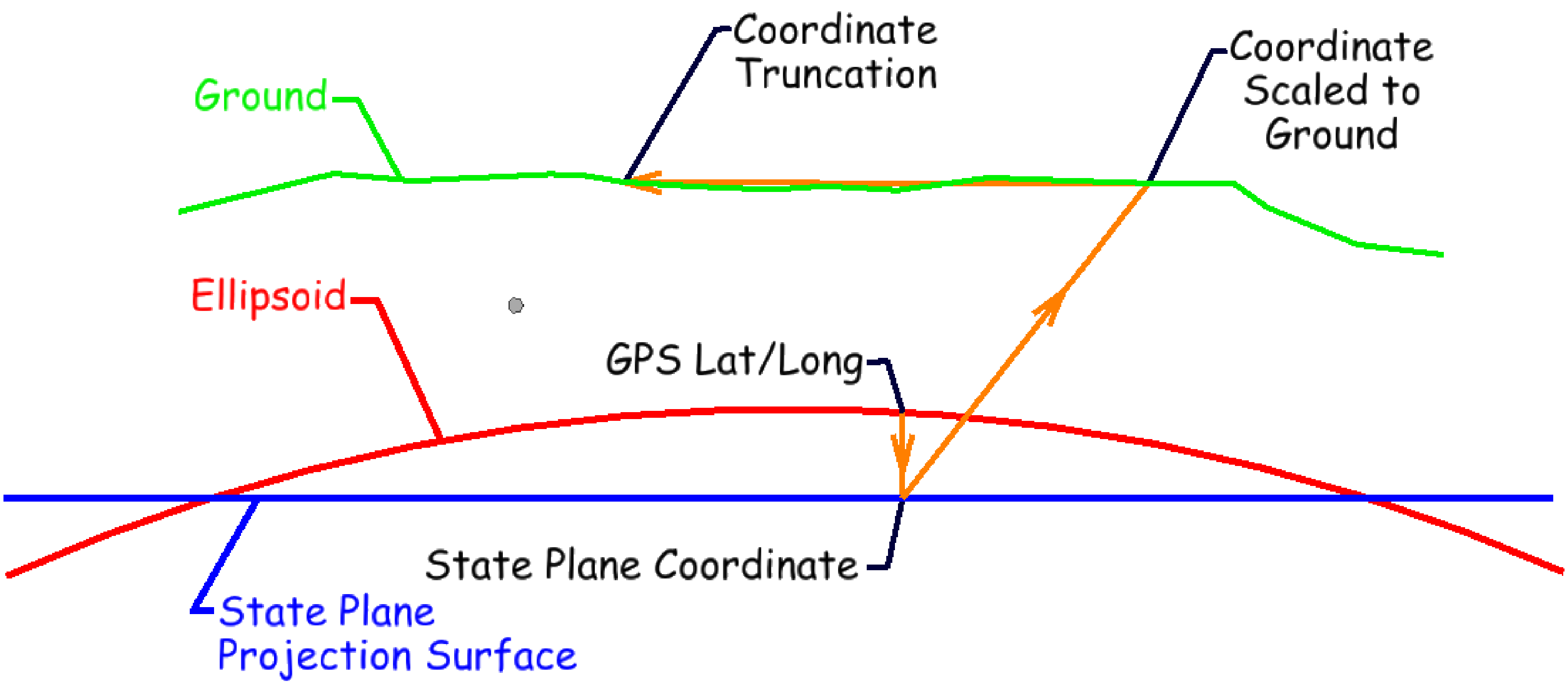
Advantages

- Project area is easily expanded
- Coordinate system is easily reproduced
- Compatible with all GPS & GIS office and field software
- Data is easily reprojected onto another coordinate system

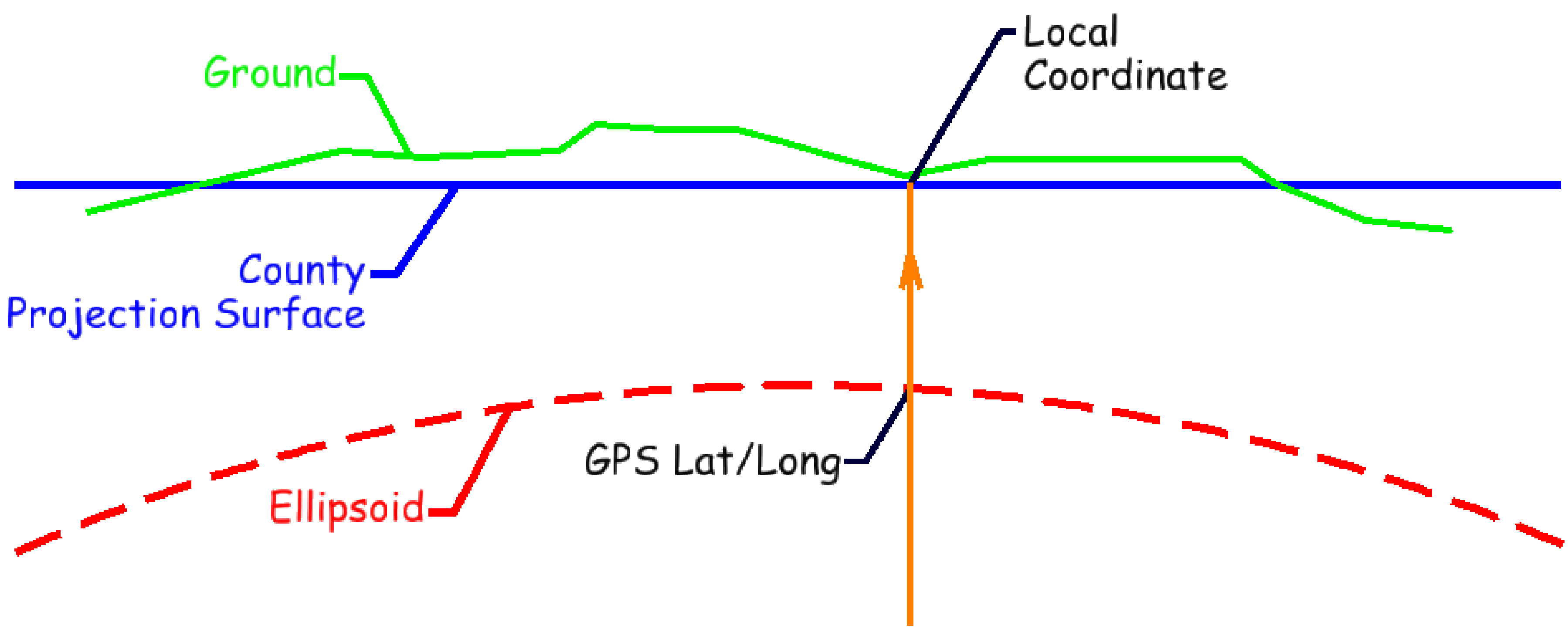
Disadvantages

- Large sites and sites with large elevation changes may need to have multiple zones which makes control more difficult to manage

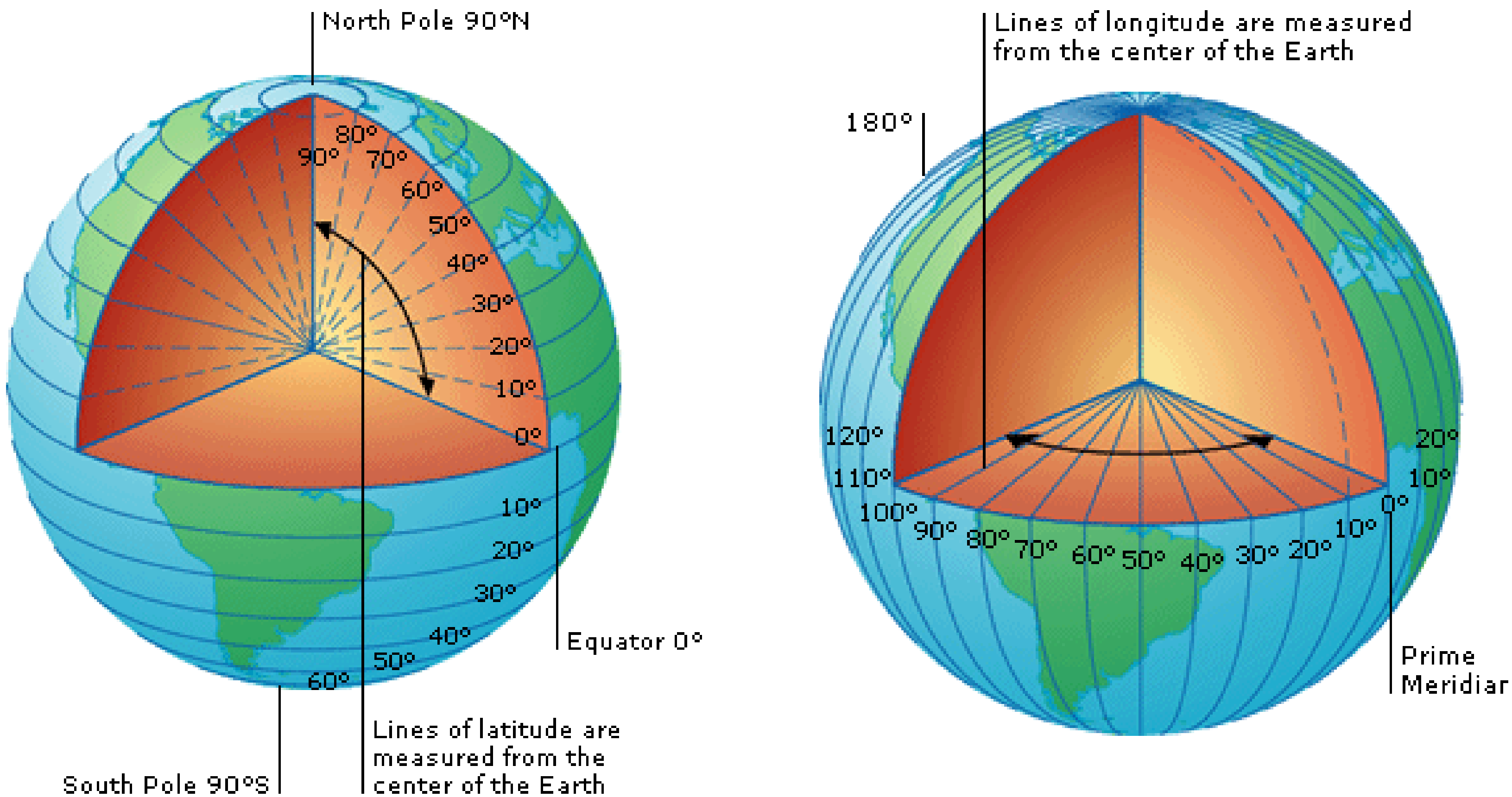
# Coordinate Scaled to Ground



# Coordinates in a County Coordinate System

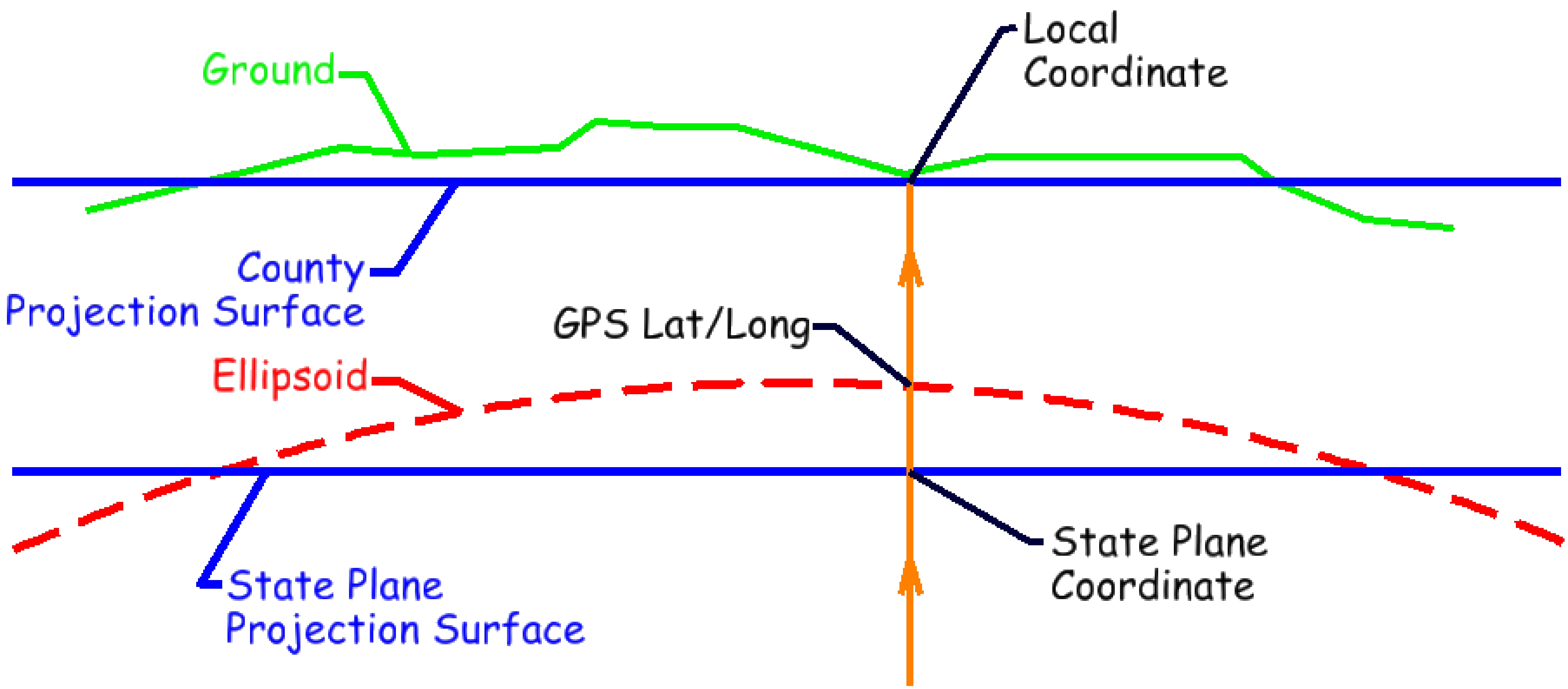


# Latitude & Longitude




http://www.factmonster.com/dk/encyclopedia/mapping.html

# Reprojecting



# Reporting

IC 32-19 Indiana Coordinate Systems
Zones Defined – "Indiana Coordinate System of 1983, East & West Zones"

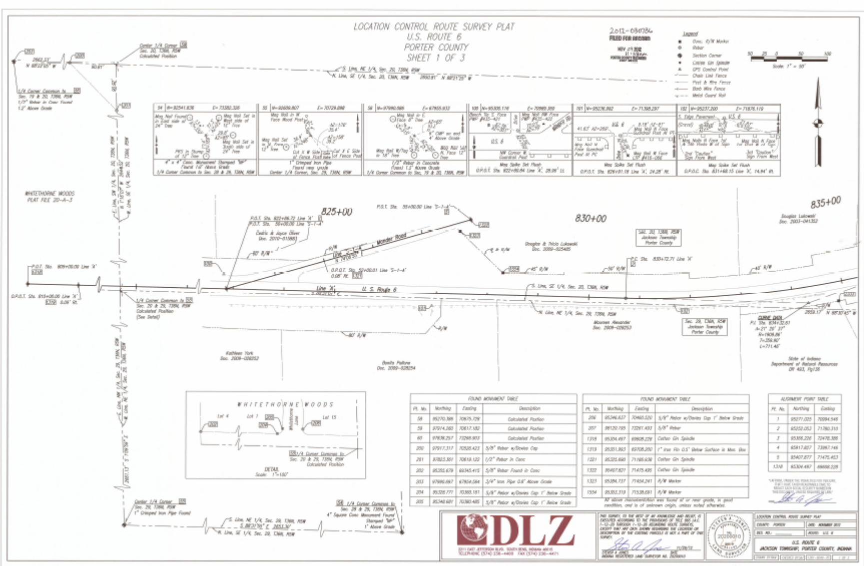
To reproduce a coordinate on the ground requires the following:
1) Coordinate System
2) Adjustment
3) Tie to a geodetic control monument
4) Method of survey used

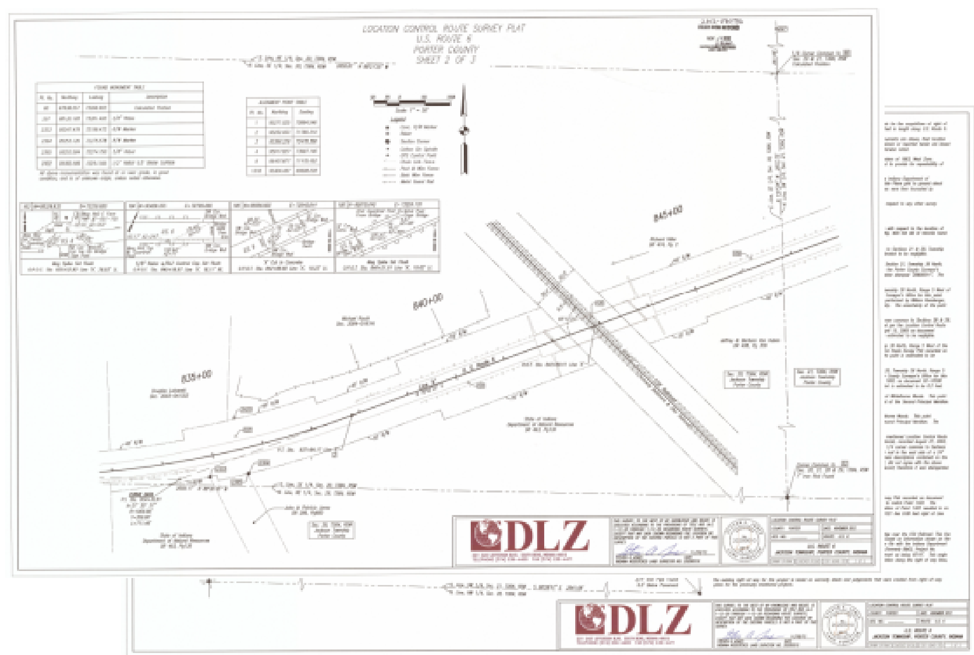
if scaled to ground:
5) Combined factor applied
6) Coordinates of scale point
7) Amount of translation (truncation)
8) Rotation (if any)

# Reporting Coordinates

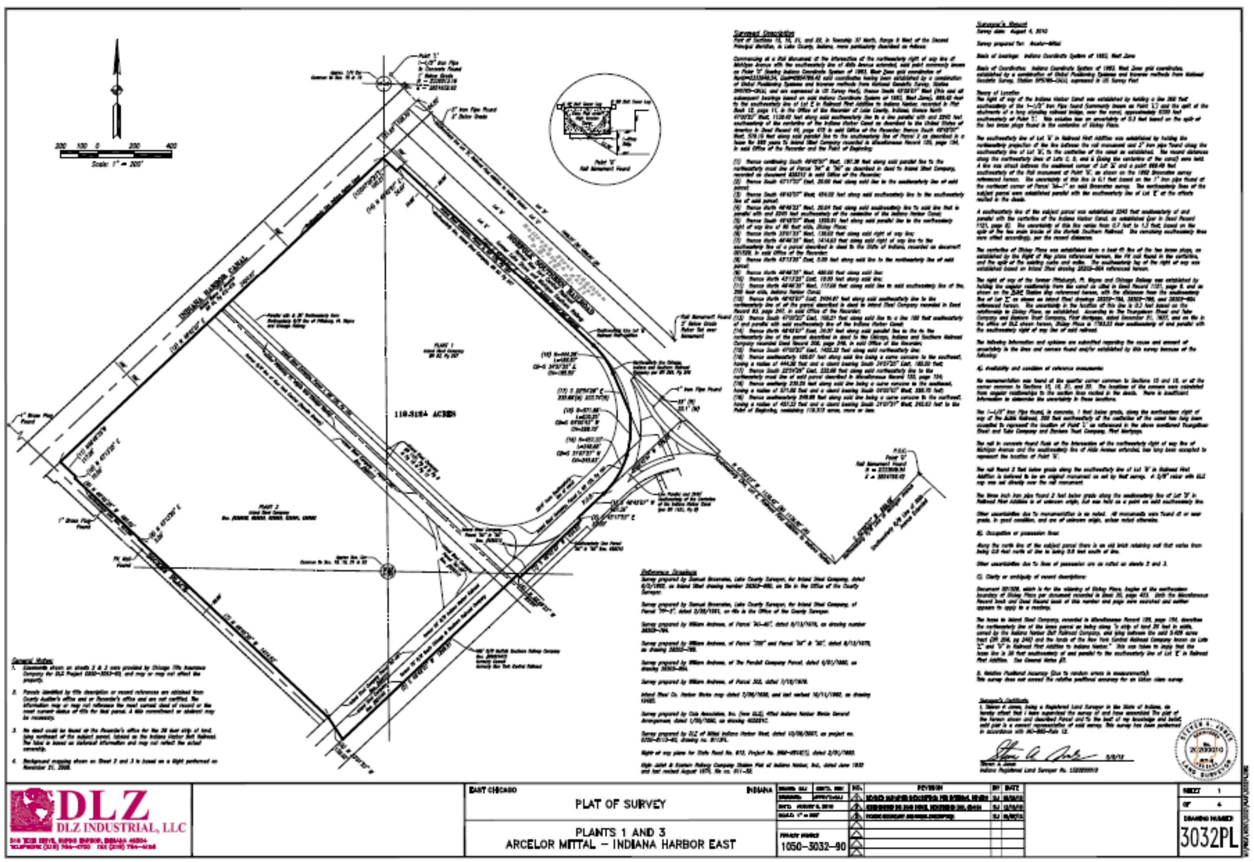
*The project coordinate system and basis of bearings are relative to the Indiana Coordinate System of 1983, West Zone. Coordinates are shown to three decimal places not to indicate the accuracy of the survey, but to provide for repeatability of calculations. Linear dimensions and coordinate values are in U.S. Survey feet.*

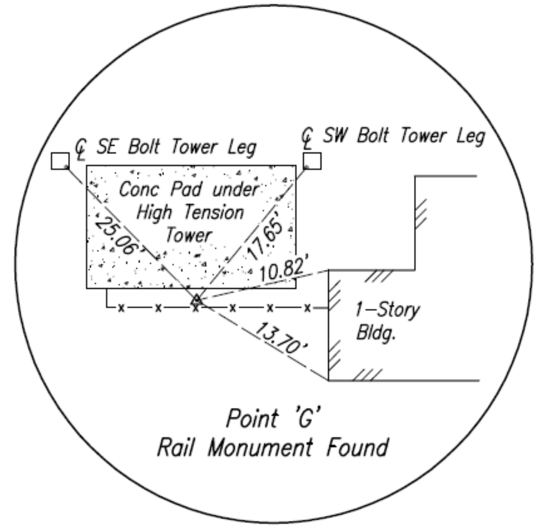
*Primary horizontal survey control was established using Real Time Kinematic methods from the Indiana Department of Transportation, Continuously Operating Reference Network. Coordinates were scaled from the State Plane grid to ground about Point #104 using a Combined Scale Factor of 0.99993657 (Ground to Grid). Coordinate values were then truncated by 2,200,000 in the Northing and 2,900,000 in the Easting.*



# Coordinates in Legal Descriptions



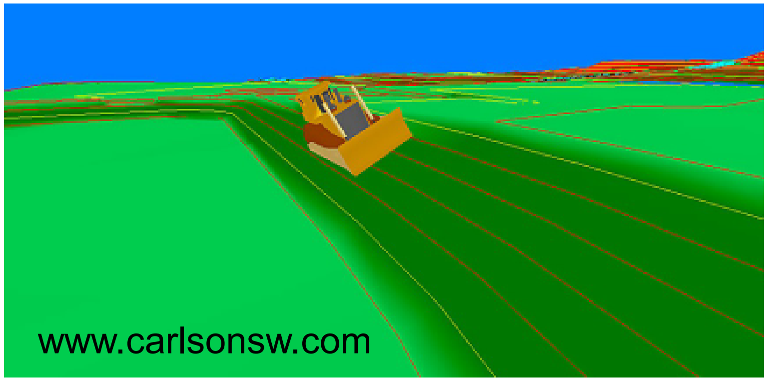
# Coordinates in Legal Descriptions

*Commencing at a Rail Monument at the intersection of the northwesterly right of way line of Michigan Avenue with the southwesterly line of Aldis Avenue extended, said point commonly known as Point 'G' (having Indiana Coordinate System of 1983, West Zone grid coordinates of North=2333849.54, East=2854796.42 said coordinates having been established by a combination of Global Positioning Systems and traverse methods from National Geodetic Survey, Station DF5765–CALU, and are expressed in US Survey Feet), thence South 42°58'07" West (this and all subsequent bearings based on said Indiana Coordinate System of 1983, West Zone), 669.48 feet to the southwesterly line of Lot E in Railroad First Addition to Indiana Harbor, recorded in Plat Book 12, page 11, in the Office of the Recorder of Lake County, Indiana; thence North 47°00'23" West, 1139.42 feet along said southwesterly line to a line parallel with and 2245 feet southeasterly of the centerline of the Indiana Harbor Canal as described to the United States of America in Deed Record 44, page 472 in said Office of the Recorder; thence South 46°42'07" West, 579.10 feet along said parallel line to the southeasterly line of Parcel 2 as described in a lease for 999 years to Inland Steel Company recorded in Miscellaneous Record 125, page 154, in said Office of the Recorder and the Point of Beginning;*

# Potential for Geographic Data

Transportation Information Modeling

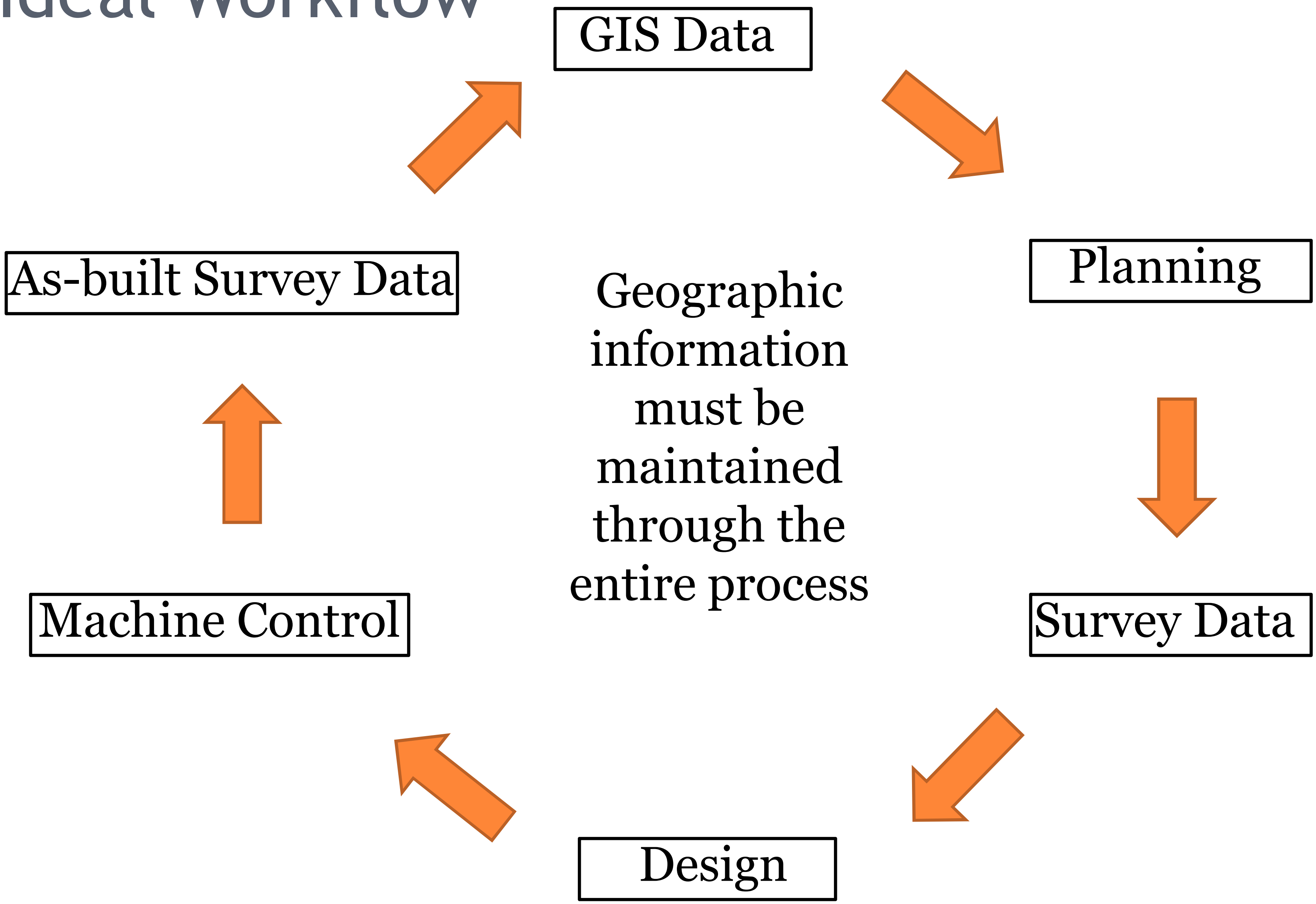

Self Driving Vehicles




Machine Control


Augmented Reality

# Ideal Workflow



# References


- National Geodetic Survey www.ngs.noaa.gov
- U.S. Army Corps of Engineers, Engineering Manual 1110-1-1003 and 1110-1-1004
- www.colorado.edu/geography/gcraft/notes/gps/gps.html
- GPS for the Land Surveyor - 2nd Addition
- Trimble Survey Controller Manual
- NDOT Surveying Standards
- INDOT Surveying Standards
- Leica  Geosystems, Smartnet Portal
- httpsalidade.wikispaces.comIndiana+SPCS+Zones
- www.Autodesk.com