Indiana Geospatial Coordinate System (InGCS)

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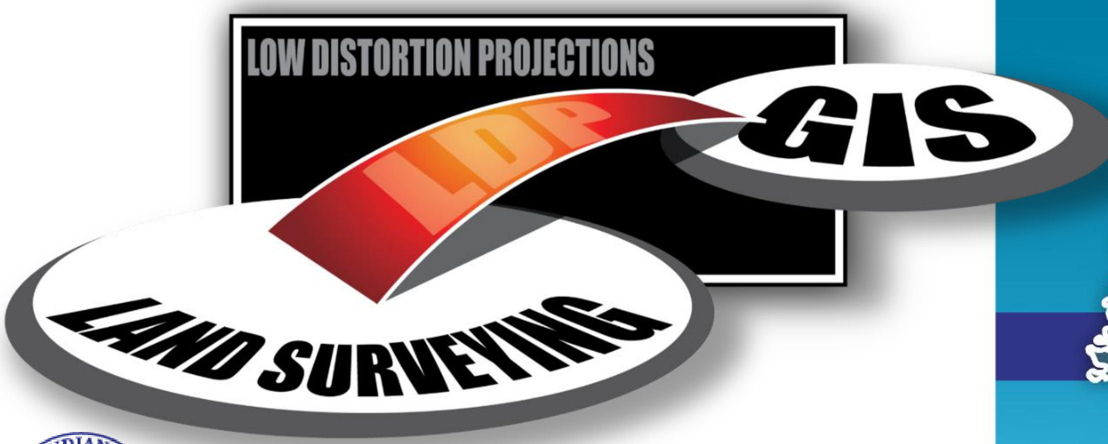
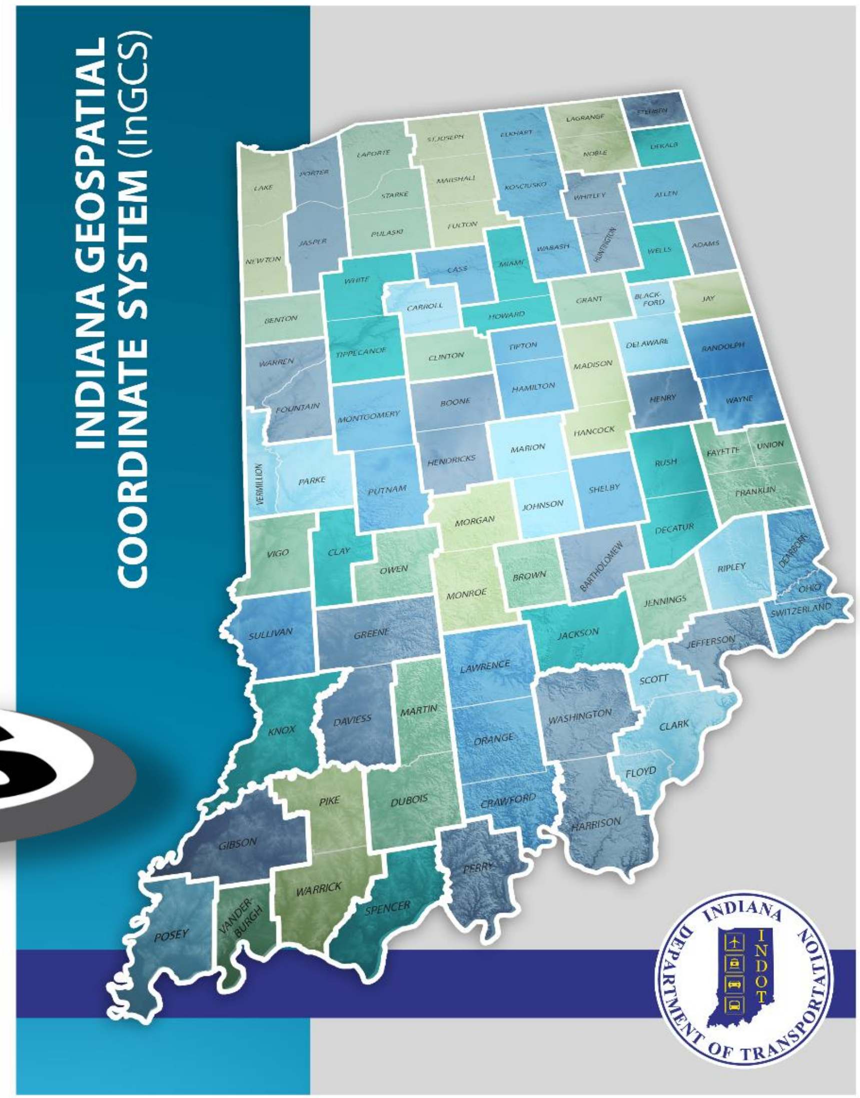
Indiana Geospatial Coordinate System (InGCS)

The Indiana Geospatial Coordinate System (InGCS)

A new coordinate reference system designed to bridge the data and workflow gap between Land Surveying, GIS, and the larger geospatial community.





Indiana's Geospatial Community

- Land Surveyors
- Civil Engineers
- Photogrammetry, Remote Sensing and GIS Professionals
- Construction Industry
- Agriculture
- Military
- Police
- Fire Departments
- Emergency Medical Staff
- Geocachers
- The General Public (on-board GPS, OnStar, etc.)
- Etc., etc.

Geospatially-Friendly Work Environment

At the end of the (work) day, all geospatial sectors/industries have their own different "needs" to complete their tasks at hand.

Being geospatially-friendly involves the ability to *accurately, precisely, quickly, and seamlessly* share georeferenced data with the rest of the community.

Geospatially-Friendly Work Environment

Consider the following:

- What's the benefit to the rest of the geospatial community of having Land Surveying data that's very representative of ground-measured horizontal distances, if the data is cumbersome to work with?
- What is the benefit to Land Surveying or Civil Engineering projects having geospatial data that is very neat, clean, has well-documented metadata, and can easily be transformed or reprojected from one reference frame to another if it is not representative of ground surface/terrestrial-based measurements?

Geospatially-Friendly Work Environment

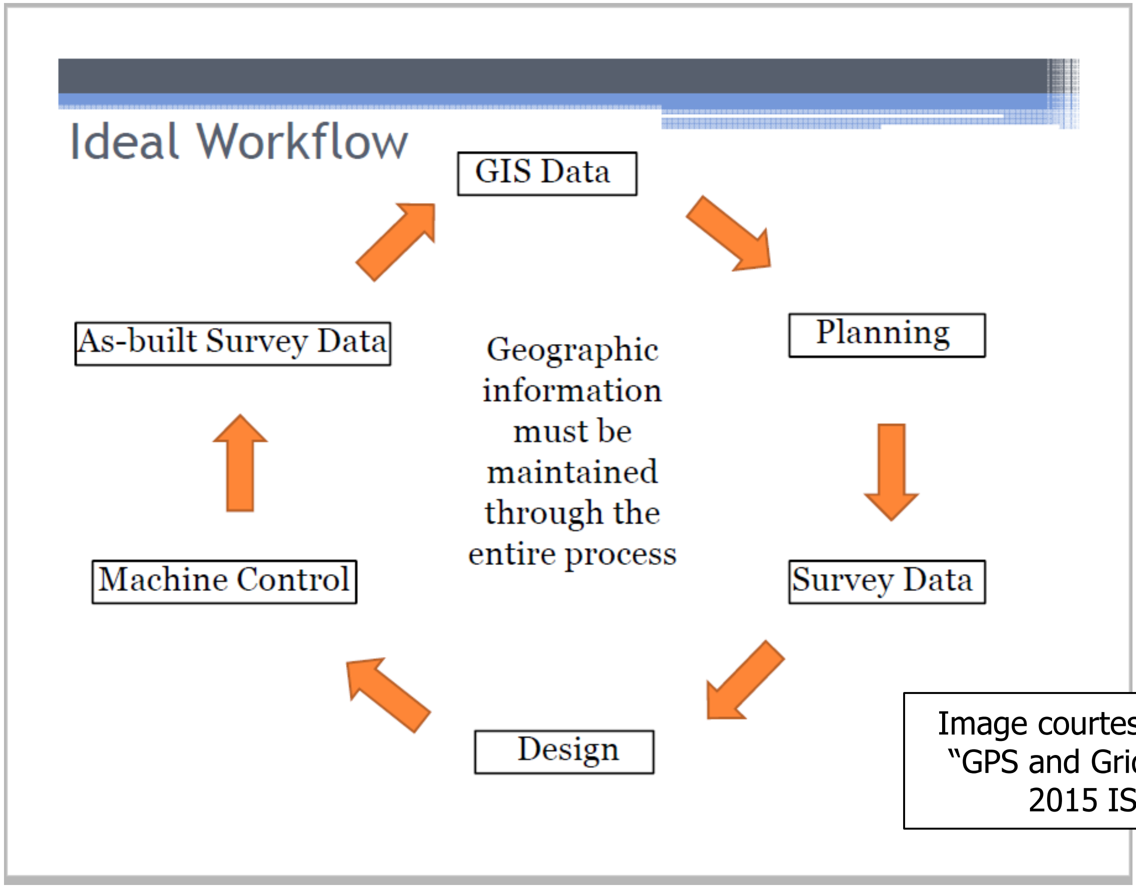


Image courtesy of Steven Jones, PS
"GPS and Grid to Ground" seminar
2015 ISPLS Convention

Land Surveying and the larger Geospatial Community

Can we all really work well together, without sacrificing our respective roles or identities or the quality of our work?

Yes!

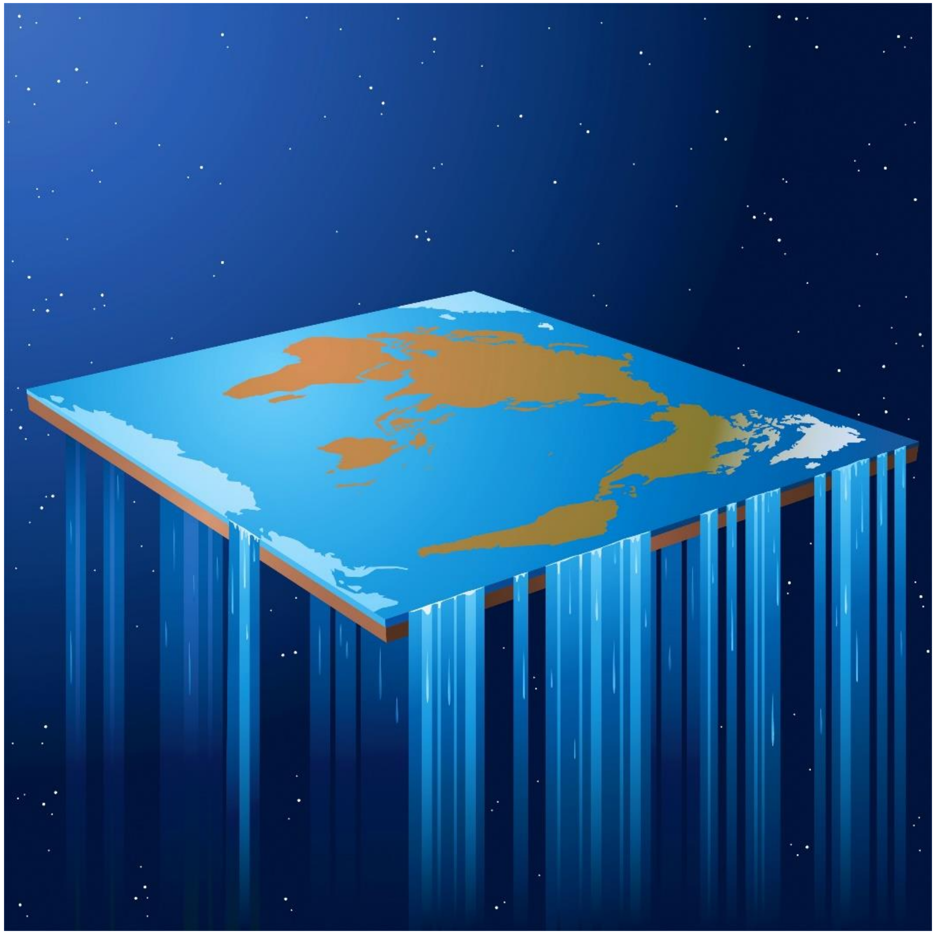
One way is with the use of
properly georeferenced data and
published map projections.

Map Projections

Emphasis placed on the plural case of "Projection(s)"

Why do we have more than one map projection?

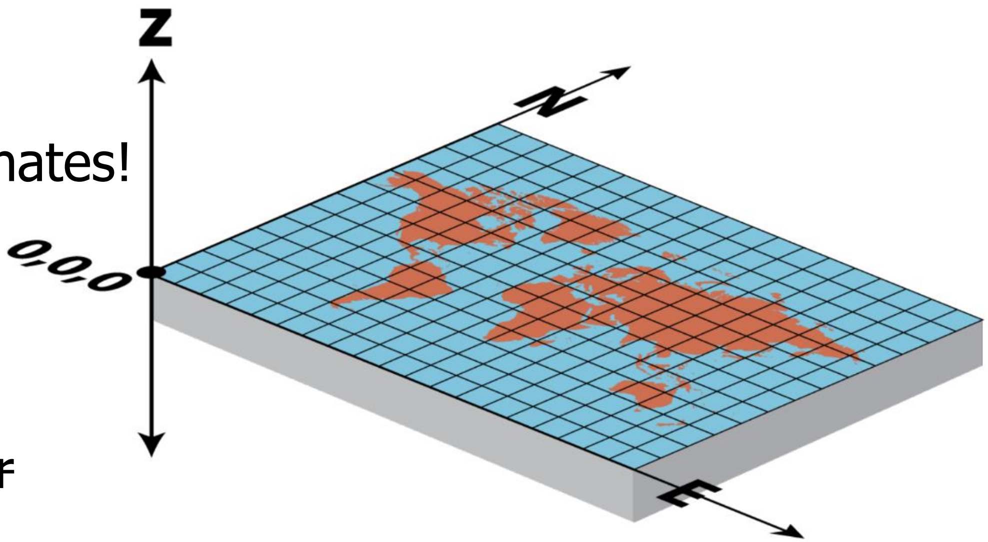
Isn't the Earth flat???



Map Projection-Flat Earth

If the Earth were indeed flat, a **single** map design could satisfy all mapping applications.

- No distortion!
- One bearing system!
  - ~~Convergence Angles~~
- One system of grid coordinates!
- Grid=Ground
  - ~~Grid Scale Factor~~
  - ~~Elevation Scale Factor~~
  - ~~Combined Scale Factor~~



Map Projection-Flat Earth (?)

But, nevertheless…

Raymond Walsh-"Man on the Lam"

It seems that the Earth is round after all.

Map Projections-Round Earth

With the Earth being round (oblate spheroid), we turn to map projections to provide us with flat, developed surfaces to represent our products:

- Aerial Photography
- Topographic Maps
- Land Survey Plats
- Design Plans
- Tax maps
- Etc., etc.

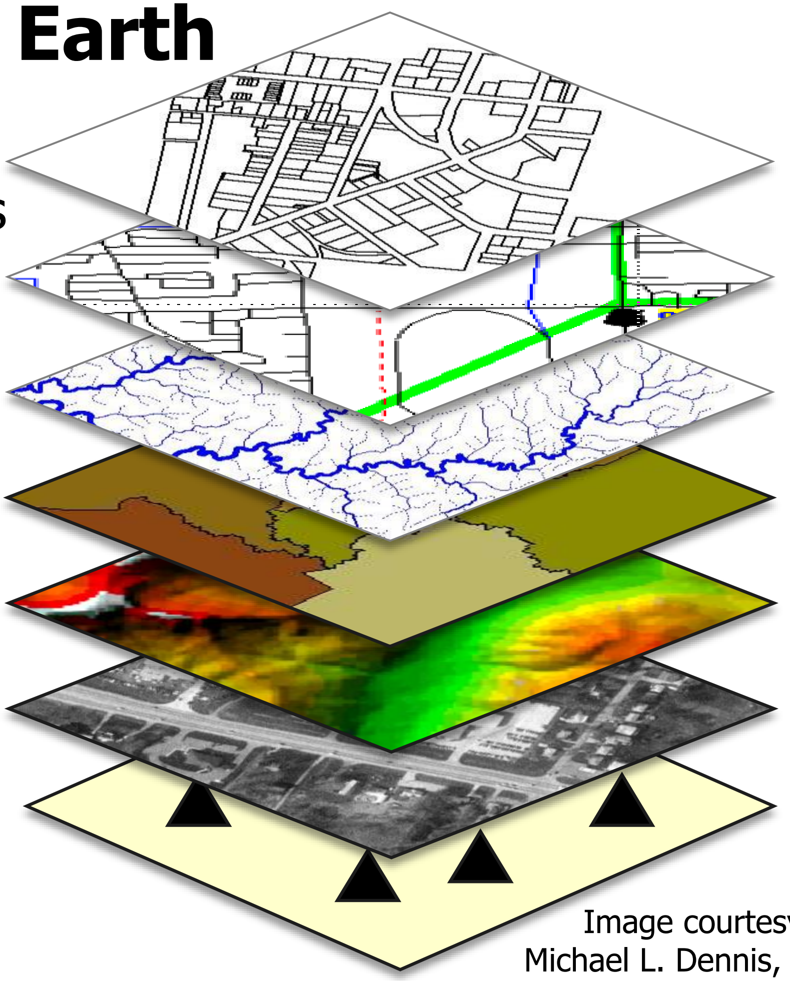


Image courtesy of Michael L. Dennis, RLS, PE

Existing Map Projections

Given the various geospatial needs of the public and private sectors, is there a "one size fits all" map projection?

There's more than one to choose from…

Existing Map Projections

Breakthroughs in positioning technology have indeed increased the ease of accurately determining the geographic positions of points on, above, or below the surface of the Earth.

Many users outside of Land Surveying, Civil Engineering, GIS, etc. may be only concerned with navigating from Point "A" to Point "B" with no thought at all for map projection selection.

Four Freedoms Monument
Evansville, Indiana

Existing Map Projections

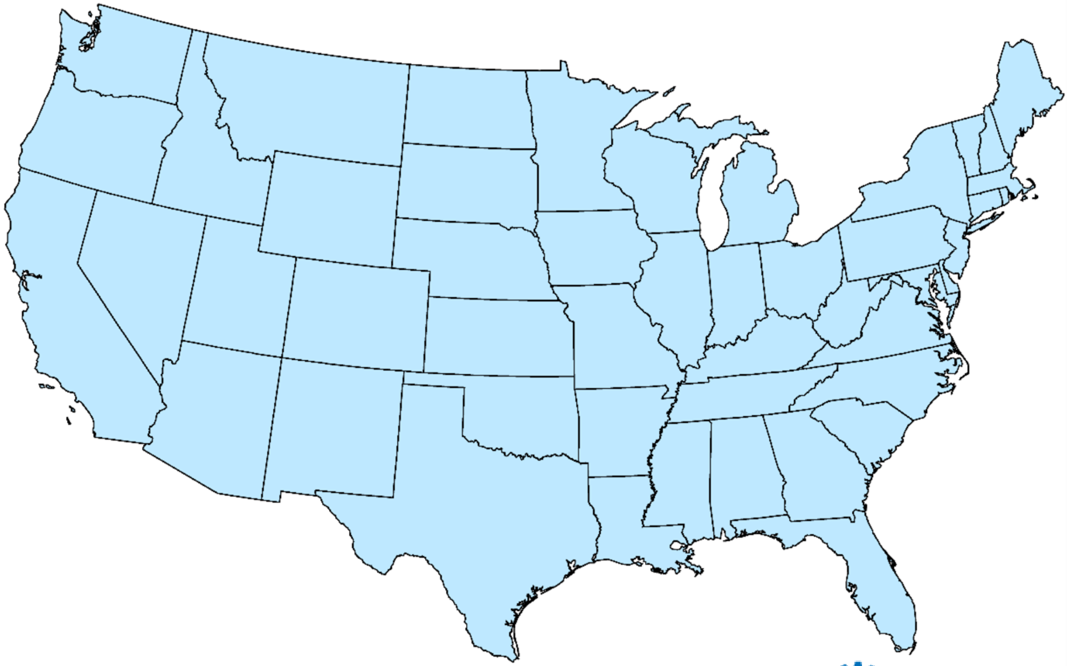
Currently-available projected coordinate systems applicable to Indiana (from ArcMap 10.1):

- World Mercator

Existing Map Projections

Currently-available projected coordinate systems applicable to Indiana (from ArcMap 10.1):

- USA Contiguous Lambert Conformal Conic



Existing Map Projections

Currently-available projected coordinate systems applicable to Indiana:

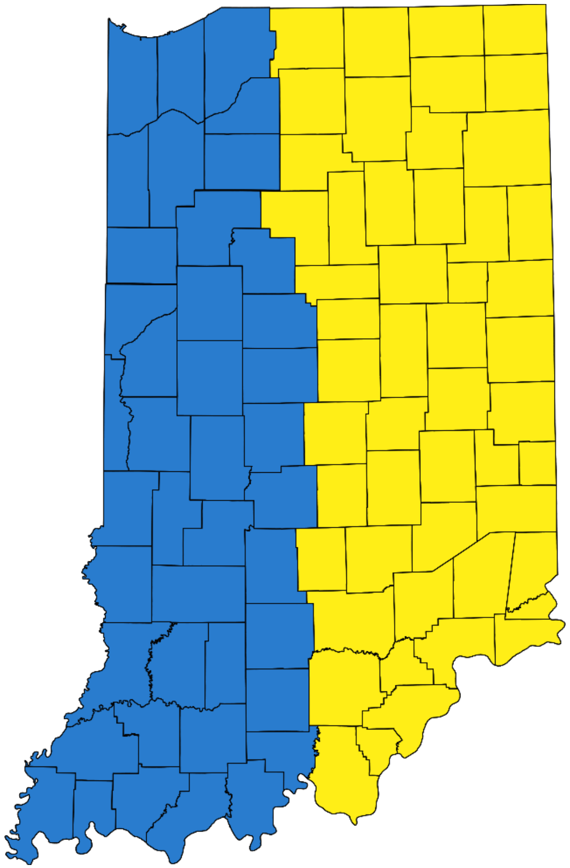
- Universal Transverse Mercator, Zone 16

Chrismurf at English Wikipedia

Existing Map Projections

Currently-available projected coordinate systems applicable to Indiana:

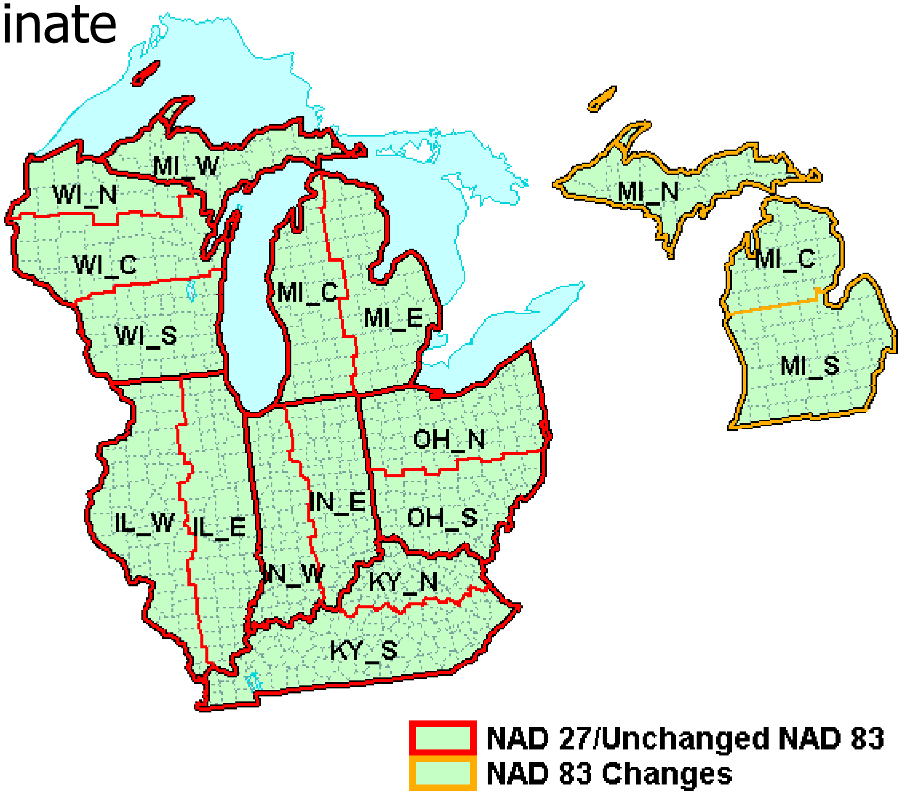
- Indiana State Plane East Zone (1301)
- Indiana State Plane West Zone (1302)



Existing Map Projections

Currently-available projected coordinate systems applicable to Indiana:

- Illinois East Zone
- Kentucky Single Zone
- Kentucky North Zone
- Kentucky South Zone
- Ohio South Zone
- Ohio North Zone
- Michigan South Zone



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

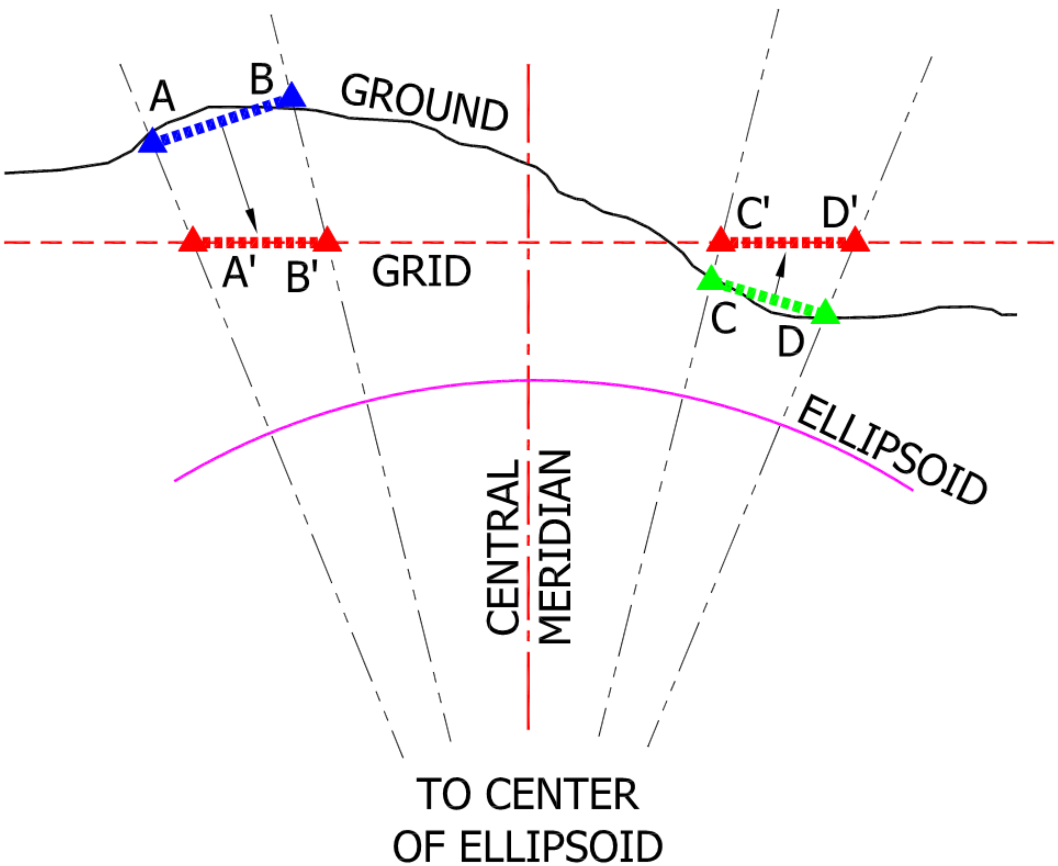
Existing Map Projections

With all these different projections already in place and in software, why are we talking about additional projections?

Grid vs. Ground

Map Projections & Grid vs. Ground

"Grid vs. Ground" refers to the difference in distance between a pair of projected grid (map) coordinates when compared to the ground-measured horizontal distance.



Generally expressed as:

- Feet per mile
- Parts per million (PPM)

Example: 1′/mile=±189ppm

Map Projections & Grid vs. Ground

"Grid vs. Ground" at "Evansville CBL"

FROM STATION	ELEV.(M)	TO STATION	ELEV.(M)	ADJ. DIST.(M) HORIZONTAL	ADJ. DIST.(M) MARK - MARK	STD. ERROR (MM)
0	139.640	150	137.933	149.9993	150.0090	.2
0	139.640	430	134.227	430.0004	430.0344	.3
0	139.640	1830	128.838	1829.9939	1830.0257	.5
150	137.933	430	134.227	280.0011	280.0256	.2
150	137.933	1830	128.838	1679.9944	1680.0191	.3
430	134.227	1830	128.838	1399.9931	1400.0035	.2

Map Projections & Grid vs. Ground

"Grid vs. Ground" at "Evansville CBL"

The NGS-published, ground-measured horizontal distance between

1830 M
G BADGER

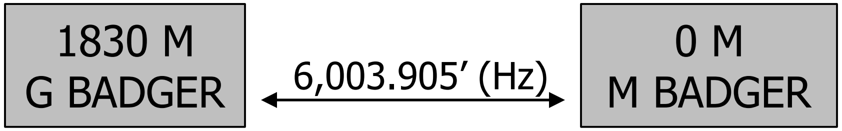
and

0 M
M BADGER

is 1,829.9939m (6,003.905')

Map Projections & Grid vs. Ground

"Grid vs. Ground" at "Evansville CBL"



Computed grid distances between these two stations using different map projections.

Projection	Grid Distance	Difference	PPM
World Mercator	7,626.6′	+1,622.7′	+270k
USA Contiguous Lambert Conformal Conic	5,971.8′	-32.1′	-5.3k
UTM zone 16	6,001.642′	-2.26′	-377
Indiana State Plane, West zone	6,003.786′	-0.12′	-20

Note: Typical "Grid vs. Ground" difference for IN SPCS is ±0.25′/mile (±47 ppm), and is upwards of ±0.4′/mile (±76 ppm).

Map Projections & Grid vs. Ground

The magnitudes of these “Grid vs. Ground” differences may be suitable for some applications, but not all.

Basing projects upon these native systems, while working with the advanced measuring equipment available today and using prudent measurement techniques, is somewhat like walking around in the wrong size of shoes.

How do we find a “better fit” for our projects?

Map Projections & Grid vs. Ground

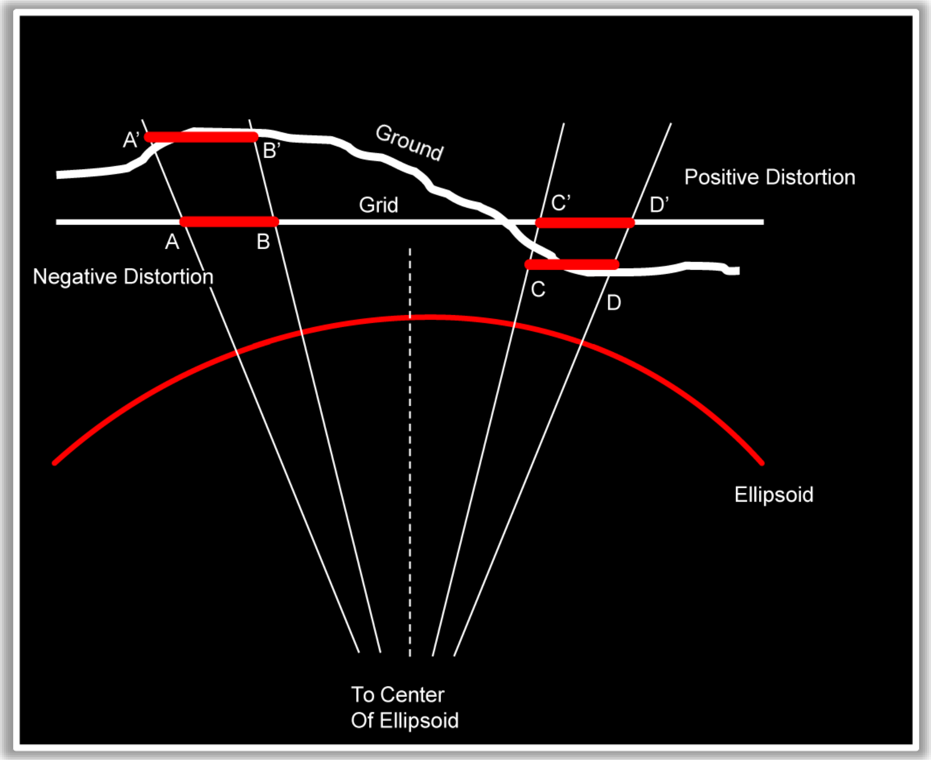
A widely-used methodology by Land Surveyors to utilize GPS/GNSS but still have “acceptable” grid-versus-ground differences…

Scale **Each** Project To Ground

Scaling Each Project to Ground

What are the advantages of scaling each project to ground?

- The mapping planes are effectively raised or lowered to approximate the (local) terrain surfaces across the limits of each project
- (Scaled) Grid Inverses ≈ Horizontal ground distances



Scaling Each Project to Ground

Typically has been prepared in two different methods:

1) Local or Arbitrary Systems
   - Tied to NSRS?…maybe just an autonomous/"here" position at the base station
   - Assign random coordinate values (N 5,000 E 5,000) at a certain physical monument
   - Bearings based upon ???
   - Still might not match other adjacent projects
   - Works well within itself!

Scaling Each Project to Ground

Typically has been prepared in two different methods:

2) Modify existing defined system (UTM, State Plane)
   - Still may not be tied to NSRS…but more likely so.
   - Coordinate values
     - Scale from origin (0,0)
     - Reassign random values at physical monument
     - Truncate coordinates at physical monument
   - Bearings typically left alone (not rotated)
   - Still might not match other adjacent projects
   - Works well within itself!

Scaling Each Project to Ground

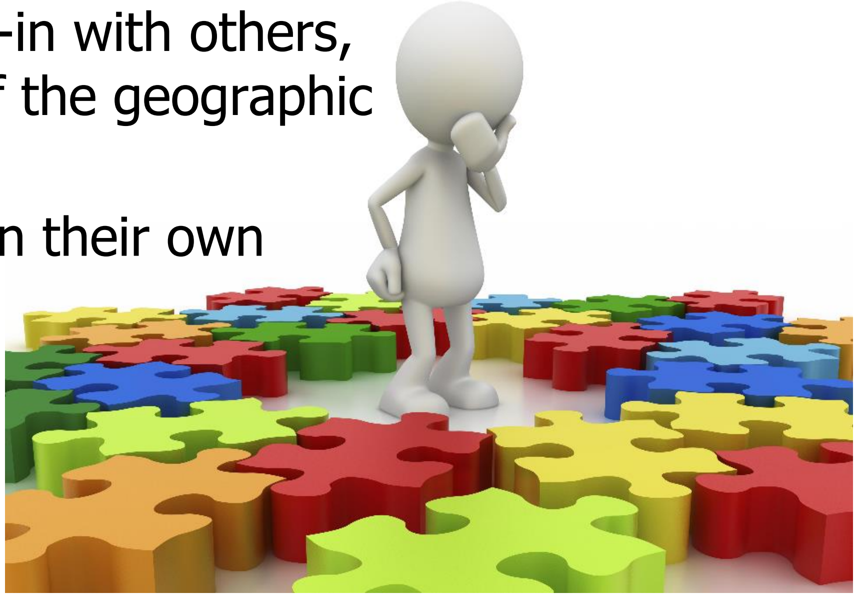
What are the disadvantages of scaling each project to ground?

- Time consuming!
    - Designing each and every new site
    - Checking computations
    - Making sure all office & field devices have the calibration file
    - Documenting calibration (internal filing and public record)

Scaling Each Project to Ground

What are the disadvantages of scaling each project to ground?

- Subsequent practitioners (Survey, GIS, etc.):
  - Discovery of the system
  - How does this project tie-in with others, i.e., how do the pieces of the geographic puzzle fit together?
  - Recreate the calibration in their own software
  - Check and recheck…
  - Distribute to crews
  - Field verifications



Scaling Each Project to Ground

What are the disadvantages of scaling each project to ground?

- It's typically only effective for smaller, site-specific projects
- Parameters for each STG project are not made commercially-available in geospatial software platforms
- Parameters may have been incorrectly documented, or not documented at all
- What happens if all local control is disturbed or destroyed?

Scaling Each Project to Ground

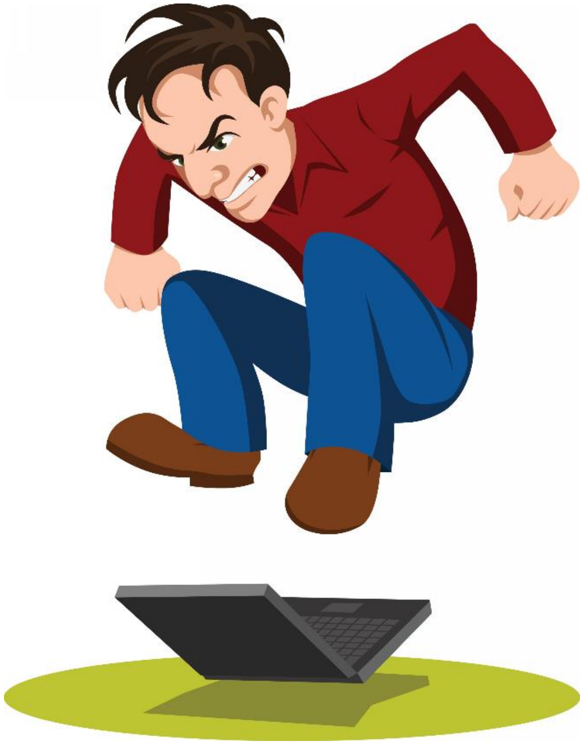
What are the disadvantages of scaling each project to ground?

- Numerous new systems!...and increasing.
  - Small regions (Section, Town, City)
  - Counties
  - Statewide
  - Nationwide

Scaling Each Project to Ground

What are the disadvantages of scaling each project to ground?

- Overlaying aerial photography?!
  - Arbitrary systems may resort to best-fitting to photo-id features
  - Modified UTM or SPC systems (scale, translate, ~~rotate?~~)



Scaling Each Project to Ground

The disadvantages of scaling each project to ground seem to far outweigh the advantages.

Let's stop scaling each project to ground!

STOP Scaling Each Project to Ground

But it's already been shown that existing map projections (SPCS and UTM) do not provide the preferred Grid vs. Ground performance for land surveying and civil engineering projects.

If we don't scale them to ground, what other option do we have???

Low Distortion Projections (LDPs)

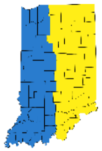
Low Distortion Projections (LDP)

What are LDPs?

LDPs have the same general flavor/purpose of their projection siblings (State Plane, UTM, etc.):

- To portray the curved surface of the Earth on a flat surface
- To satisfy the *stated goals* of the target users

Some refer to them as "miniature State Plane zones"…



Low Distortion Projections

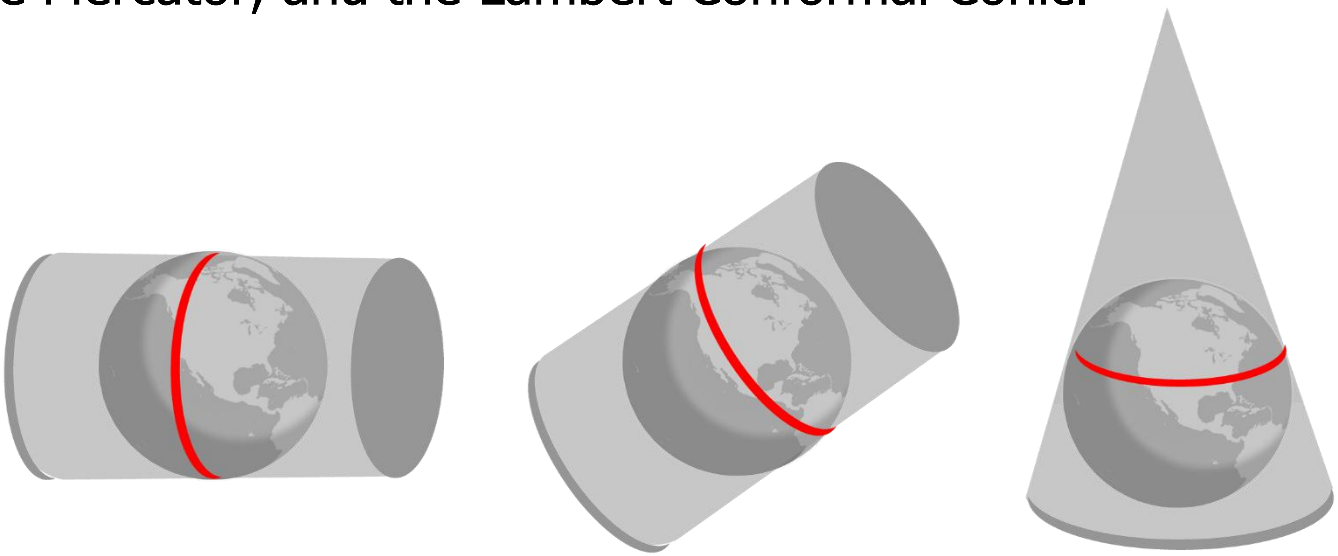
As the name itself implies, LDP's are map projections that have low or minimized linear distortion across the design region.

Distortion in still unavoidable…but LDP's can provide more tolerable linear distortions to geospatial projects.

Distortion

Low Distortion Projections

LDPs only make sense for conformal map projections, as the scale is the same in all directions. The three conformal map projections utilized in the State Plane Coordinate System are the Transverse Mercator, Oblique Mercator, and the Lambert Conformal Conic.

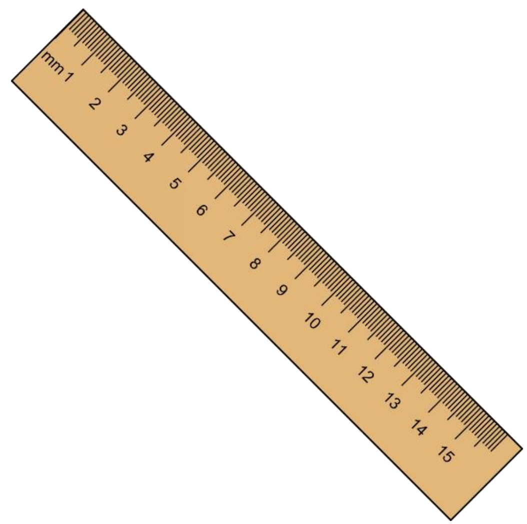


Transverse Mercator Oblique Mercator Lambert Conformal Conic

Low Distortion Projections

Two types of Distortion

- Angular: Convergence angle for conformal projections
- Linear: Difference between grid inverses (map distance) and corresponding ground/horizontal distances



Low Distortion Projections

Linear Distortion is caused by two spatial characteristics:

- Earth curvature: width of zone (perpendicular to projection axis)
- Terrain height above ellipsoid

Low Distortion Projections

Linear distortion due to Earth curvature

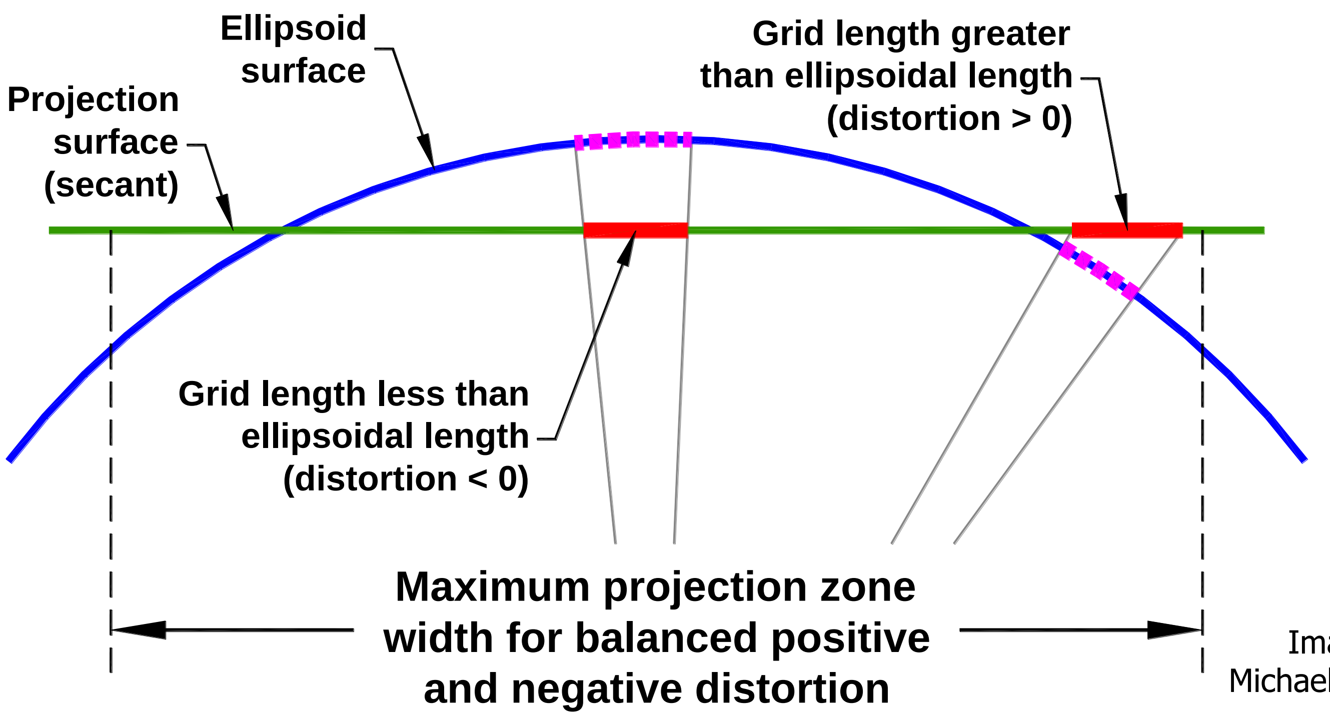


Image courtesy of
Michael L. Dennis, RLS, PE

Low Distortion Projections

Linear Distortion due to Earth curvature

Zone Width (miles)	Maximum Linear Distortion		
	PPM	Feet/Mile	Ratio
16	+/- 1	+/- 0.005	1:1,000,000
50	+/- 10	+/- 0.05	1:100,000
71	+/- 20	+/- 0.1	1:50,000
112	+/- 50	+/- 0.3	1:20,000
158	+/- 100	+/- 0.5	1:10,000
317	+/- 400	+/- 2.1	1:2,500

Low Distortion Projections

Linear distortion due to ground height above ellipsoid

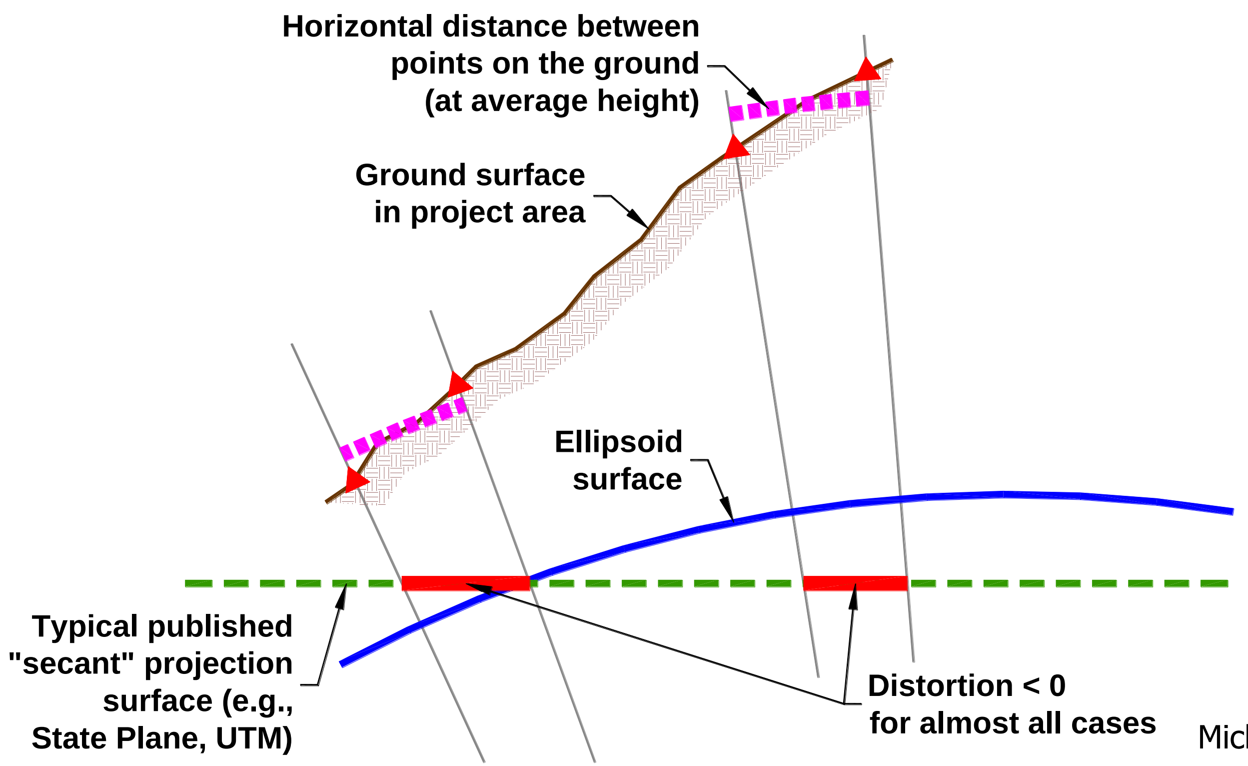


Image courtesy of
Michael L. Dennis, RLS, PE

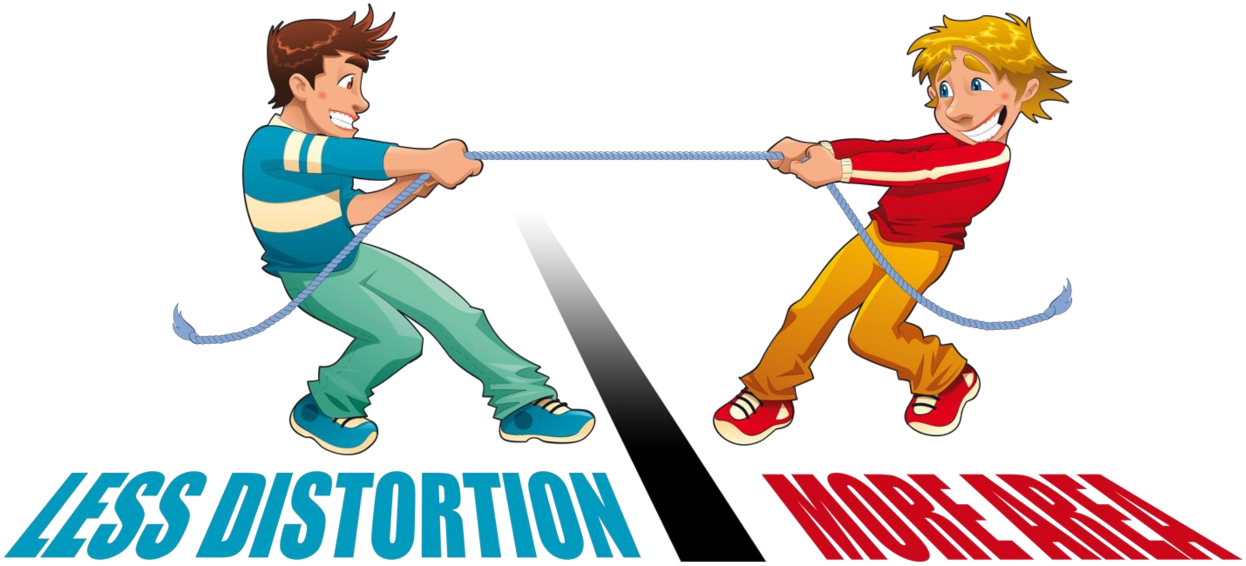
Low Distortion Projections

Linear Distortion due to height above ellipsoid

Height (ft) (above ellipsoid)	Maximum Linear Distortion		
	PPM	Feet/Mile	Ratio
100	4.8	0.03	1:209,000
400	19	0.1	1:52,000
1,000	48	0.3	1:21,000
2,000	96	0.5	1:10,500
4,000	191	1	1:5,200
7,000	335	1.8	1:3,000

Low Distortion Projections

In designing LDPs, the balance between having less distortion, yet embracing more area, are constantly at odds with one another. More area typically increases the width of the zone, which increases distortion. It potentially also means including larger differences in terrain height, which also increases distortion.



Low Distortion Projections

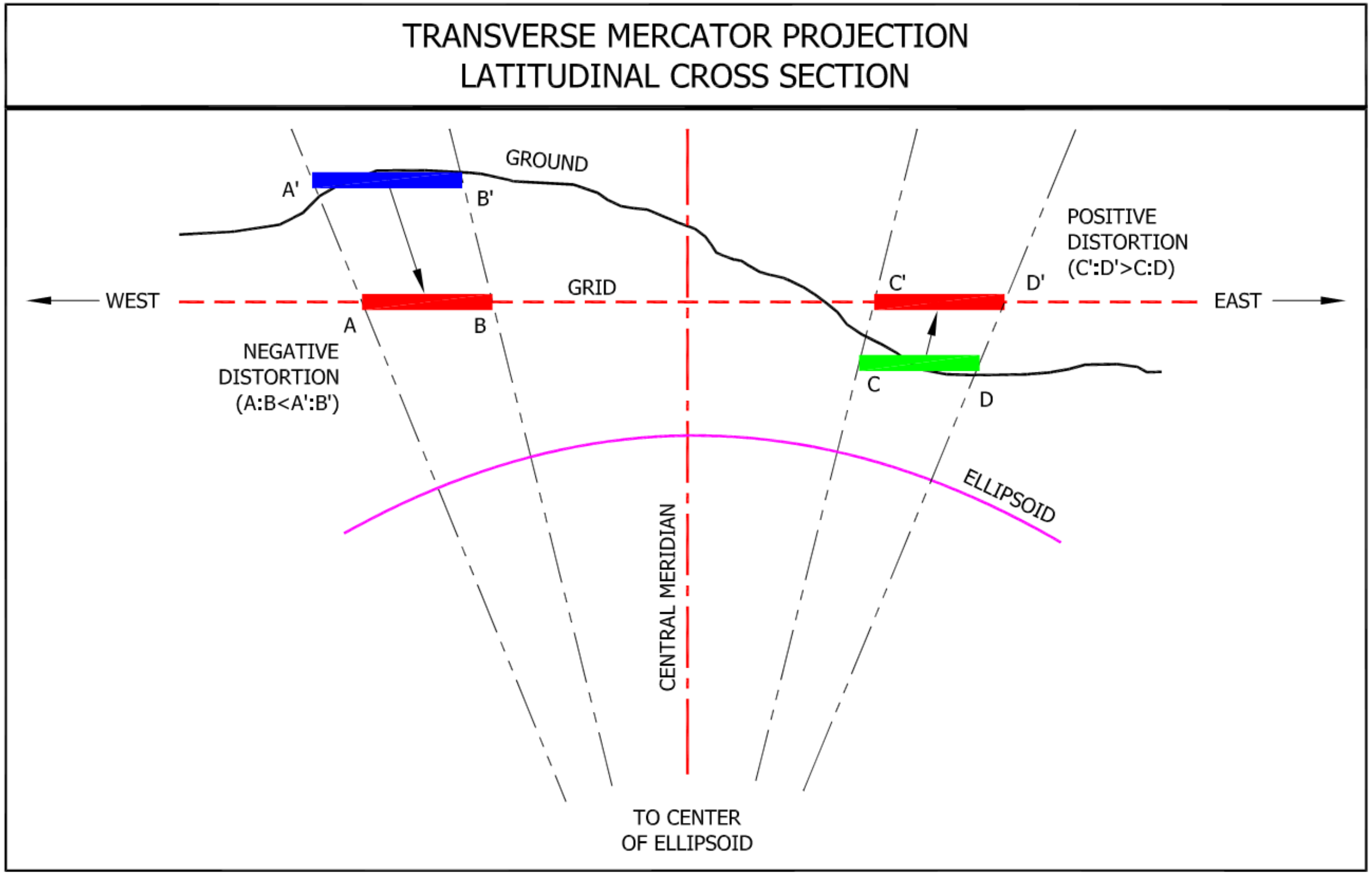
Where to set the distortion threshold for increasing the area embraced by an LDP should be determined by a Technical Development Team comprised of knowledgeable geospatial practitioners from different industries (surveying, civil engineering, GIS, etc.) advising the responsible party/agency.

Low Distortion Projections

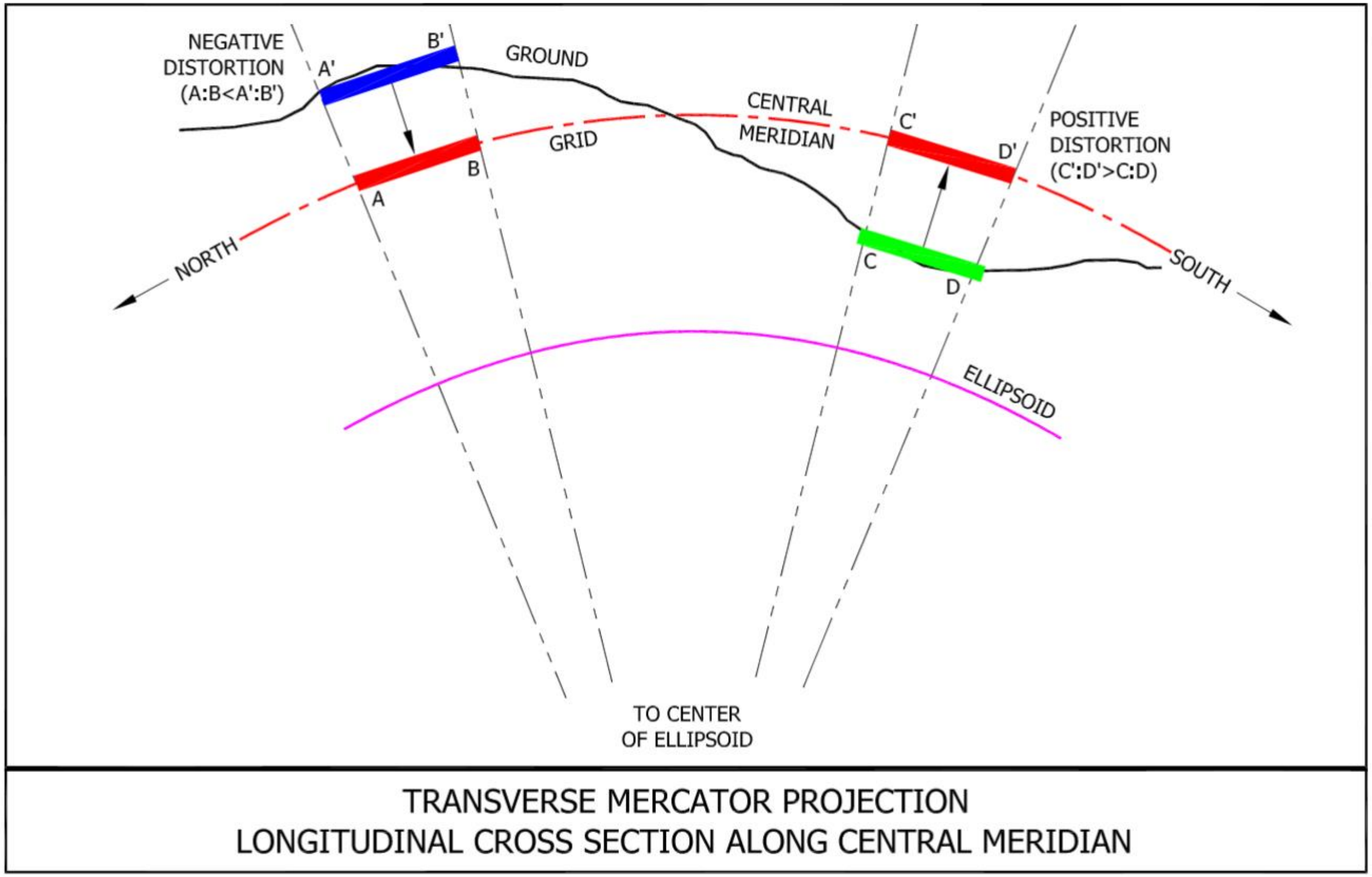
Linear Distortion can negative or positive in sign.

- Negative: Grid (map) distance is less than horizontal distance
- Positive: Grid (map) distance is greater than horizontal distance

Low Distortion Projections



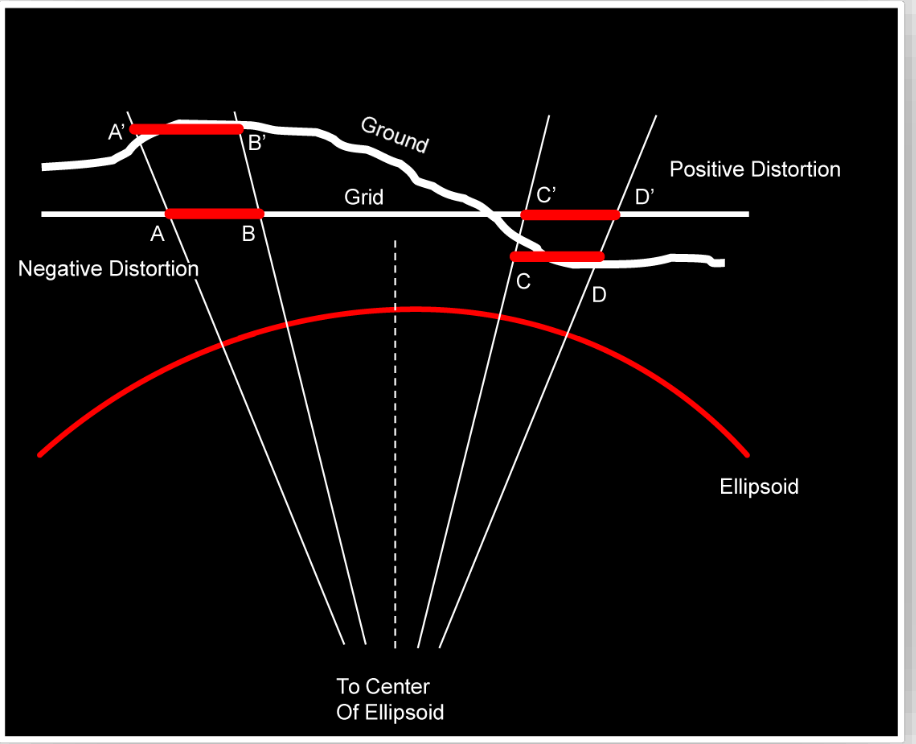
Low Distortion Projections



Low Distortion Projections

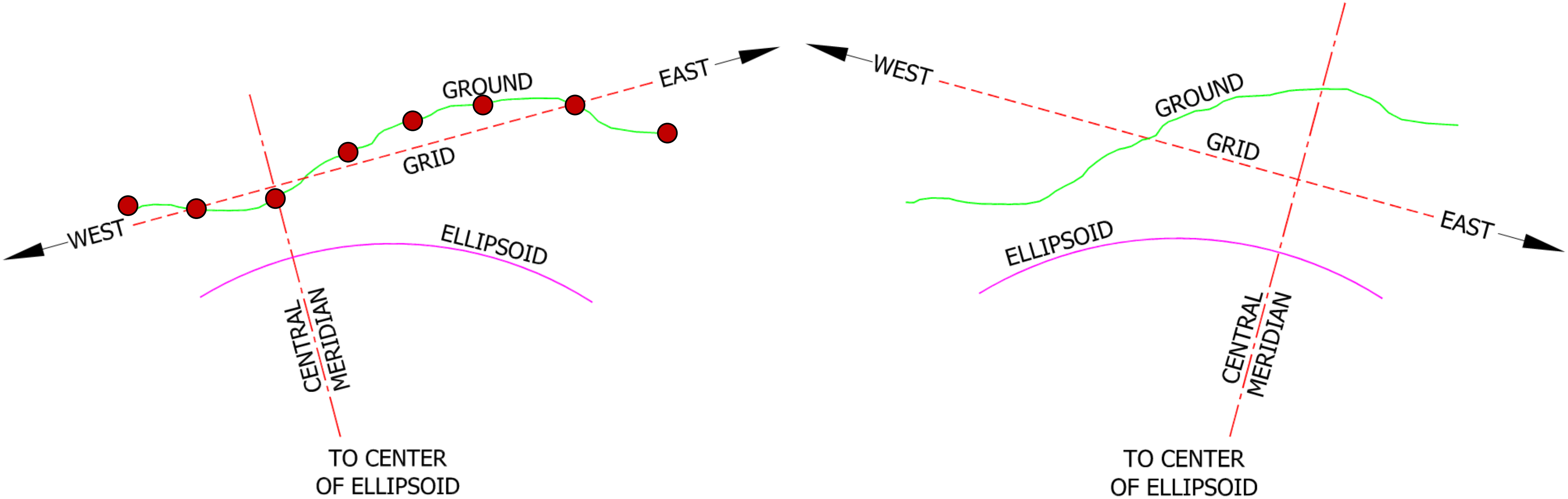
LDP's versus Scaling Each Project to Ground?

The concept of LDP's and "scaling each project to ground" are similar in that both developed mapping surfaces have been lowered or raised to approximate the terrain surface across the designated region.



Low Distortion Projections

With Transverse Mercator projections, moving the central meridians east or west helps to counterbalance regions generally sloping up/down east/west. Think "regression analysis."



Low Distortion Projections

Advantages of LDP's over "scaling each project to ground":

- Time savings
  - Quick selection of system in software
  - No design time
  - No design-validation time
  - Not constantly verifying office & field devices are up-to-date
  - Documentation (internal and public record) time reduced to the same as documenting UTM or State Plane
  - Subsequent practitioners time reduced to the same as following UTM or State Plane projects

Low Distortion Projections

Advantages of LDP's over "scaling each project to ground":

- Directly tied to the National Spatial Reference System (NSRS)
- Not anchored/dependent upon local, physical monuments
- Intended to cover much larger regions
- Can be commercially available

Low Distortion Projections

Advantages of LDP's over "scaling each project to ground":

- "Reprojections on-the-fly" from one CRS to another is a reality in many geospatial software platform (such as GIS)
  - Aerial photography
  - Polygons, Polylines, Points
  - Etc.

Low Distortion Projections

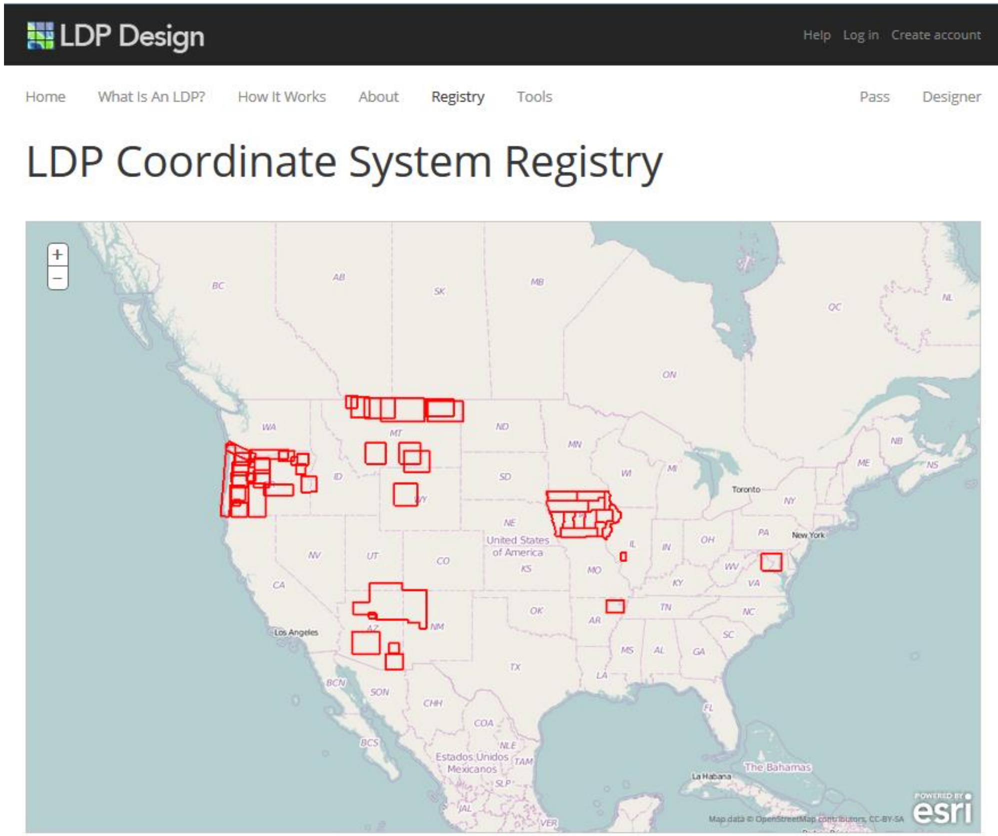
PARAMOUNT ADVANTAGE OF LDP's TO THE GEOSPATIAL COMMUNITY

When included in geospatial software platforms, LDPs offer future geospatial users a quick and easy way to fit all the different pieces (projects) of the geographic puzzle together.

Low Distortion Projections

What other regions, States, and Departments of Transportation are using LDPs?:

- Minnesota
- Wisconsin
- Oregon
- Iowa
- Washington, D.C.
- Rocky Mountain Tribal CRS
- ???



https://geo.ldpdesign.com/registry

New Projected Coordinate Reference System for Indiana

We need to know where our target (linear distortion budget) is before we draw back and begin design.

In other words, how much better does a new system need to be over the existing system (SPCS) to justify the effort required?

New Projected Coordinate Reference System for Indiana

The existing Indiana State Plane East & West Zones exhibit the following linear distortion.

State Plane East/West	Linear Distortion Statistics		
	PPM's	Ft/Mile	Ratio (1:X)
Average	47.4	0.25	21,000
95-Percentile	72.3	0.38	14,000
Maximum	75.1	0.40	13,000

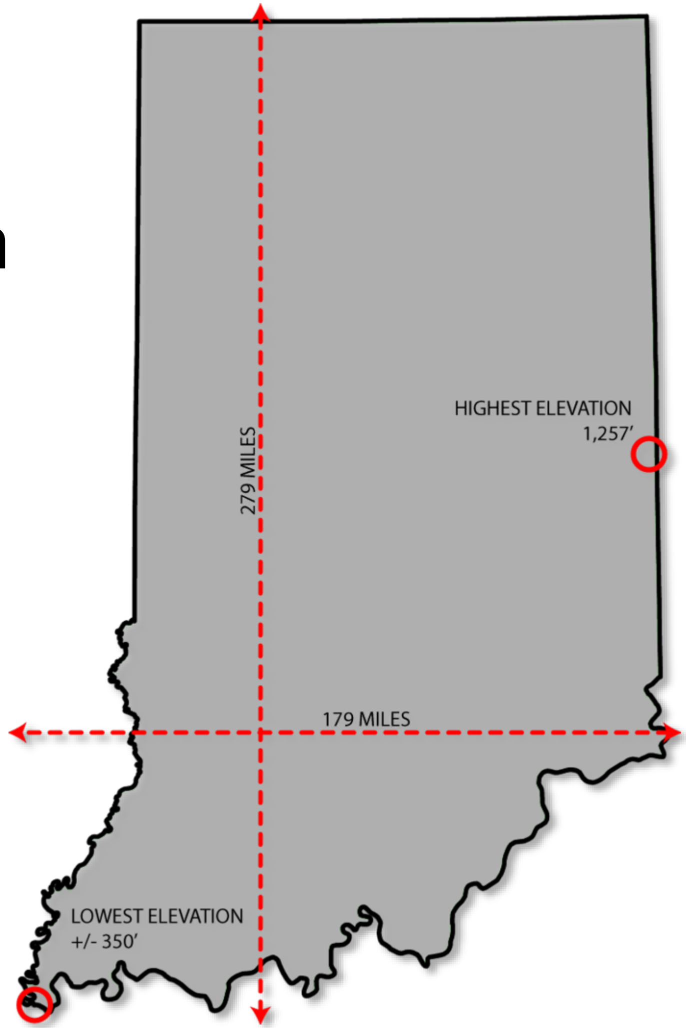
What option is "significantly" better than this?

New Projected Coordinate Reference System for Indiana

What if we designed a single LDP zone for the entire State of Indiana?

Distortion from Earth curvature: >0.55′/mile

That's worse than what we already have…



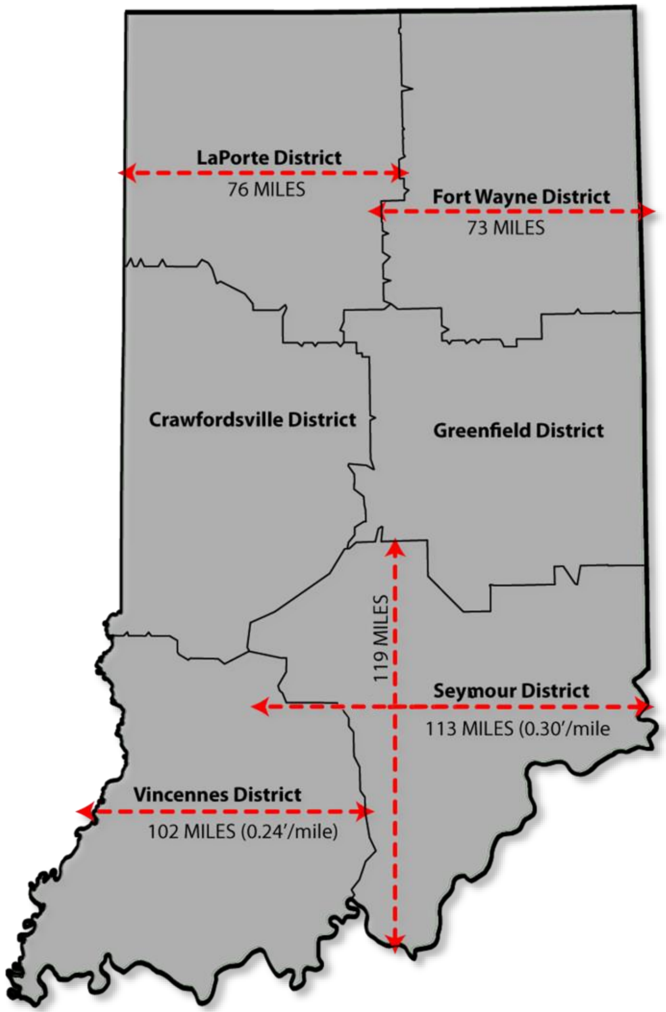
Indiana Geospatial Coordinate System (InGCS)

New Projected Coordinate Reference System for Indiana

How about INDOT Districts?

Distortion from Earth curvature: >0.30’/mile

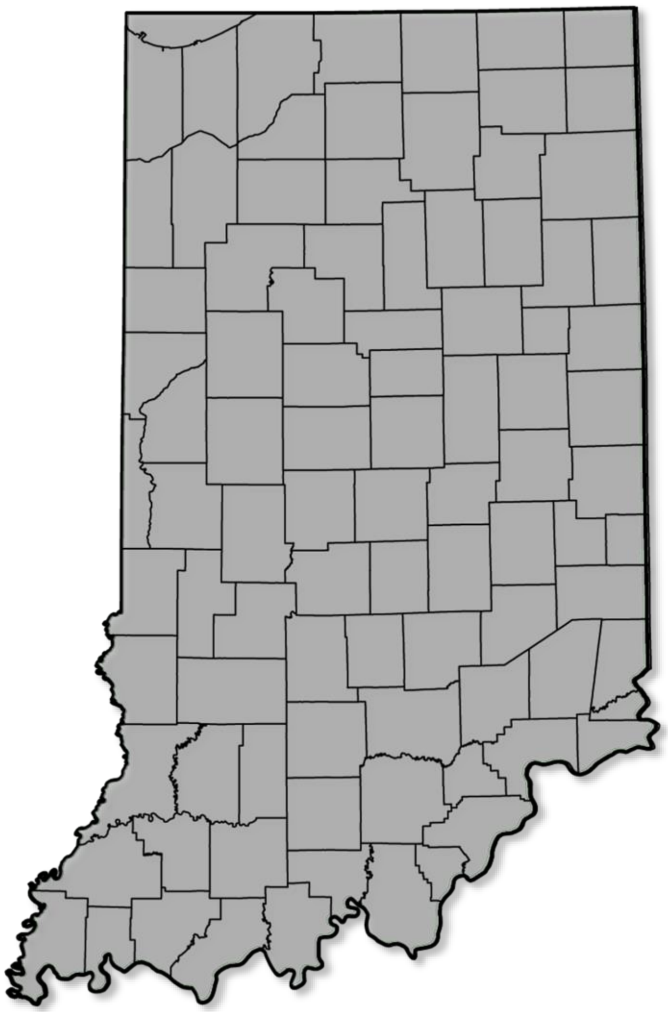
That’s not a significant improvement…



Indiana Geospatial Coordinate System (InGCS)

New Projected Coordinate Reference System for Indiana

How about county boundaries?



New Projected Coordinate Reference System for Indiana

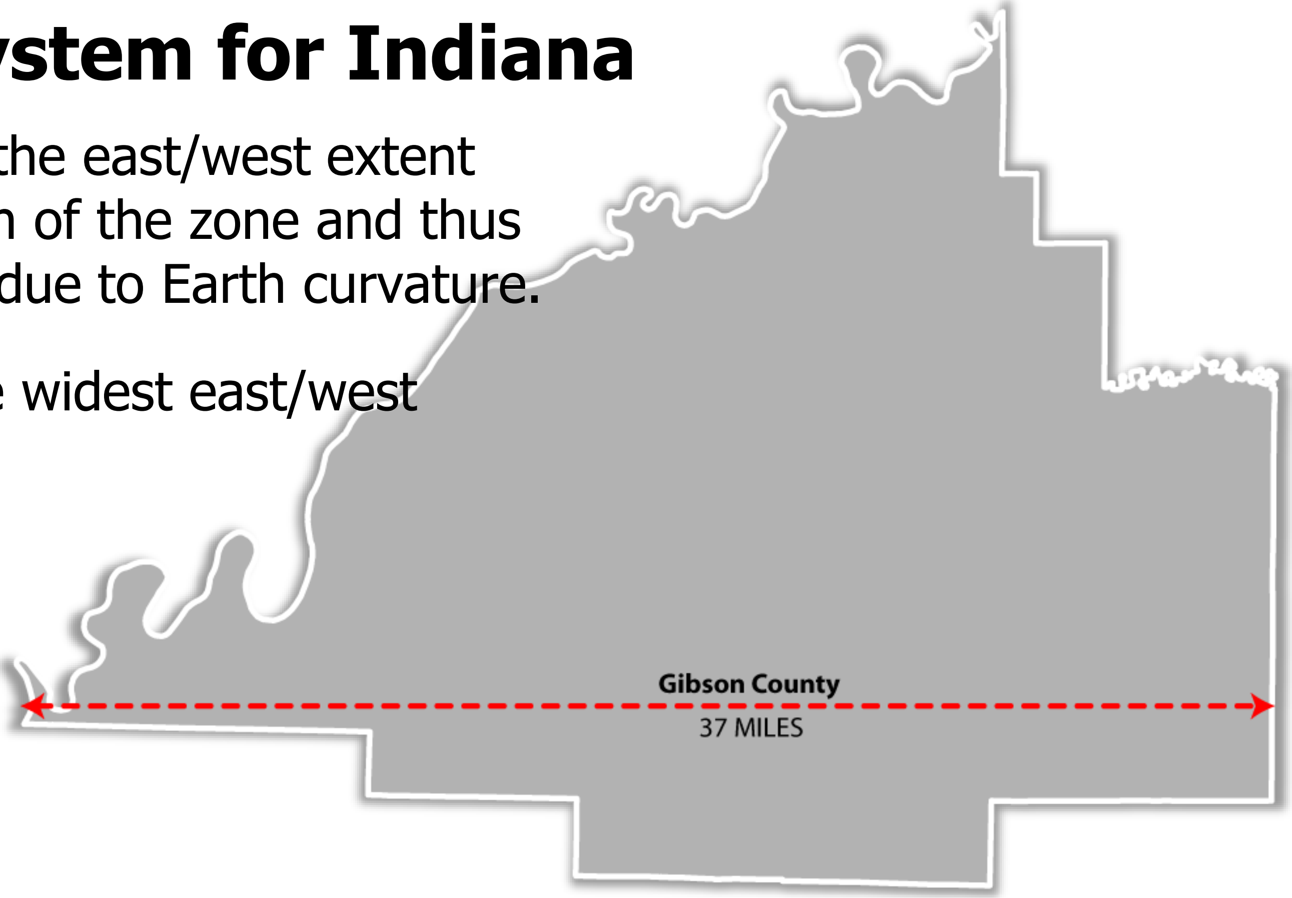
For TM projections, the east/west extent determines the width of the zone and thus the linear distortion due to Earth curvature.

Gibson County is the widest east/west Indiana county.

+/-11.0ppm

+/-0.06 feet/mile

Not too bad...



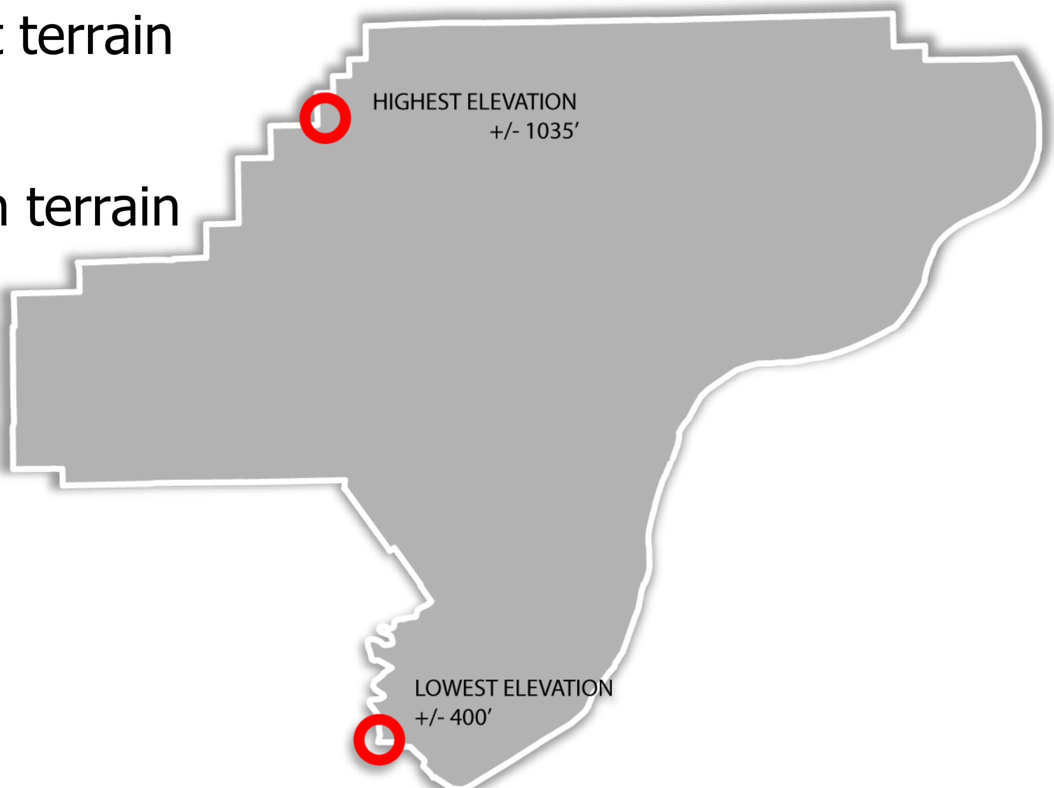
New Projected Coordinate Reference System for Indiana

Clark County exhibits the most terrain relief.

Distortion due to differences in terrain height:

+/-15.2ppm

+/-0.08 feet/mile



Still not too bad...

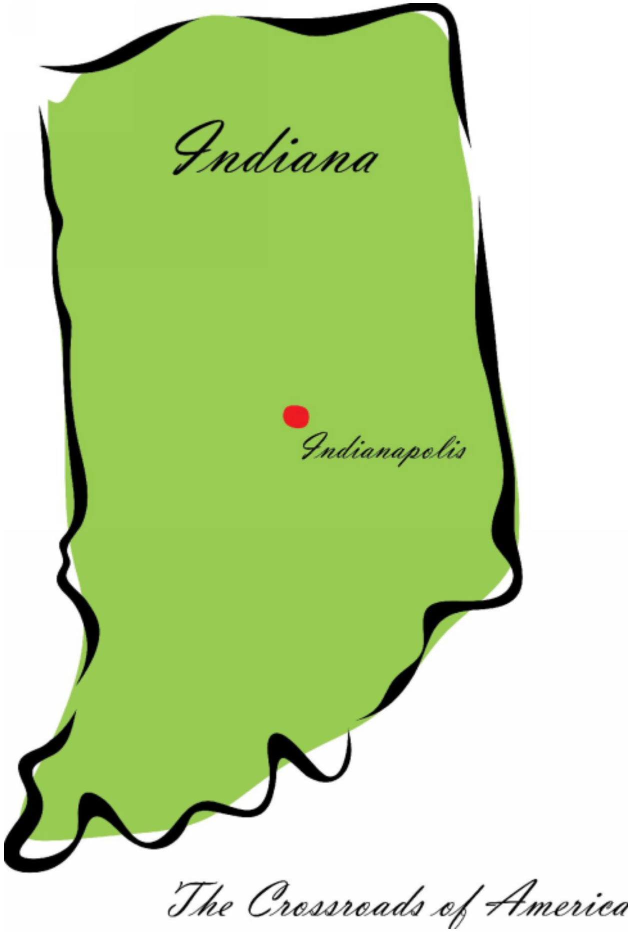
New Projected Coordinate Reference System for Indiana

County boundaries "hit the target" in order to achieve linear distortion "significantly" better than the existing Indiana State Plane East & West Zones.

InGCS: Design Goals

Summary of the stated goals of the InGCS:

- Geodetic Datum
  - Reference all projections to the National Spatial Reference System, NAD 83 (2011, +)…
- Projection Type
  - Transverse Mercator (all)



InGCS: Design Goals

Summary of the stated goals of the InGCS:

- Linear Units
  - **Define** all False Northings and Easting in **meters** that coincide with even-foot U.S. Survey Foot conversions
    - False Northing: 36,000 m=118,110- U.S. Survey Feet
    - False Easting: 240,000 m=787,400- U.S. Survey Feet
  - **Work** to be performed in **U.S. Survey Feet**

InGCS: Design Goals

Summary of the stated goals of the InGCS:

- Angular Units
  - **Define** latitude of grid origin and central meridians at even 3-minute intervals for exact conversion to decimal degrees at two decimal places

Marion County Example:

- Lat. of Grid Origin: 39°18'00" N = 39.30°N
- Central Meridian: 86°09'00" W = 86.15°W

InGCS: Design Goals

Summary of the stated goals of the InGCS:

- Central Meridian Scale Factors
  - Define to exactly six decimal places

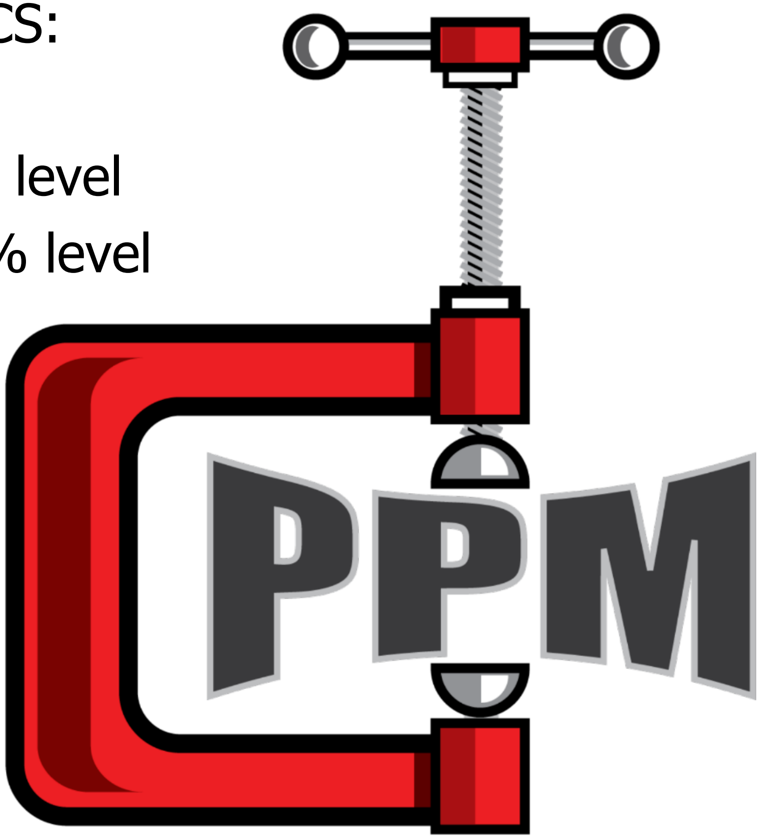
Marion County Example:

- CMSF=1.000031

InGCS: Design Goals

Summary of the stated goals of the InGCS:

- Preferred Linear Distortion Budget:
  - 5 ppm's (≈0.03′/mile) at the 95% level
  - 10 ppm's (≈0.05′/mile) at the 99% level

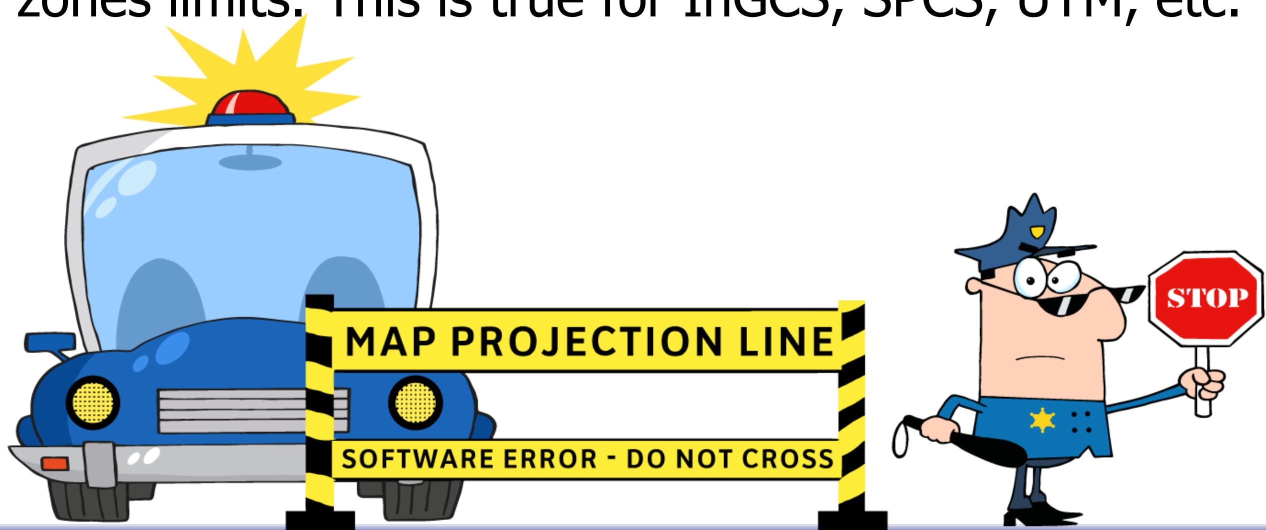


InGCS: Design Goals

Summary of the stated goals of the InGCS:

- Nominal Zone Limits/Boundaries
    - Each County will be its own "zone"

Note: Geospatial software packages perform computations beyond the "nominal" zones limits. This is true for InGCS, SPCS, UTM, etc.



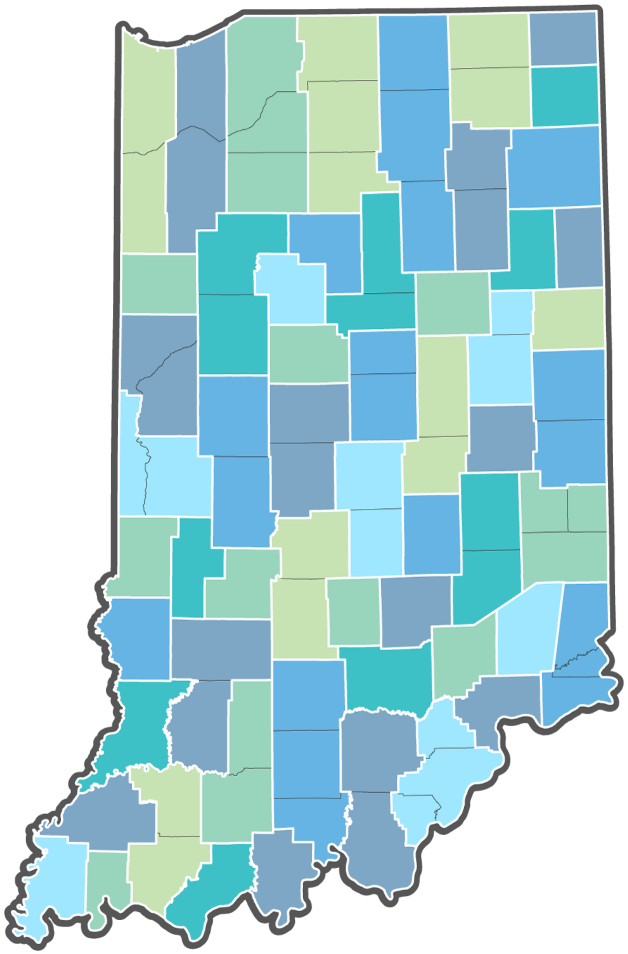
InGCS: Design Goals

Summary of the stated goals of the InGCS:

- Attempt to group Counties together, unless sacrificing PPM
  - Keep a County autonomous if combining an adjacent County would otherwise cause it to exceed the distortion budget
  - Even if an autonomous County already exceeded distortion budget, keep it autonomous if combining an adjacent County would otherwise cause the distortion to "substantially" increase
- Numerical Definitions: (see Handbook when published)

InGCS: Design Results

- Indiana has 92 Counties. From stated goals, this yields 92 zones.
- Disregarding the zone names, comparing the projection parameters of all 92 zones reveals 57 distinct sets of projection parameters.



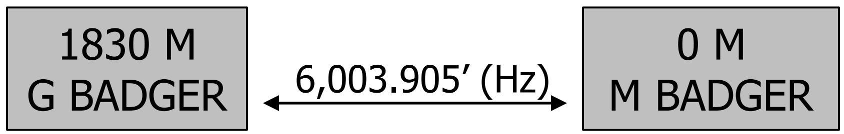
InGCS: Design Results

- InGCS Linear Distortion Statistics
  - Average ≈ 2.6 ppm's (0.014'/mile)
  - Worst sampled linear distortion: 23.4 ppm (≈0.12'/mile)

…back to the "Evansville CBL." How did the "Vanderburgh" zone perform there?

Flashback: Map Projections & Grid vs. Ground

"Grid vs. Ground" at "Evansville CBL"



Computed grid distances between these two stations using different map projections.

Projection	Grid Distance	Difference	PPM
World Mercator	7,626.6′	+1,622.7′	+270k
USA Contiguous Lambert Conformal Conic	5,971.8′	-32.1′	-5.3k
UTM zone 16	6,001.642′	-2.26′	-377
Indiana State Plane, West zone	6,003.786′	-0.12′	-20
InGCS, Vanderburgh zone	**6,003.903′**	**-0.002′**	**-0.3**

Note: Typical "Grid vs. Ground" difference for IN SPCS is ±0.25′/mile (±47 ppm), and is upwards of ±0.4′/mile (±76 ppm).

InGCS: QC/QA

Prior to "finalizing" the results of the InGCS, a QC/QA review was performed by a different set of eyes to ensure the product.

InGCS Technical Development QA/QC

High level analysis of the methods and data and detailed check of the numbers in all documentation.

- Map Projection Methods
- Scale Factor Analysis
- Central Meridian and Latitude of Origin Locations
- False Northing/Easting Definitions
- Validation Point Coordinates
- Zone Definitions
- Zone Names – spelling, punctuation, etc.
- Numerical checks

InGCS Technical Development QA/QC

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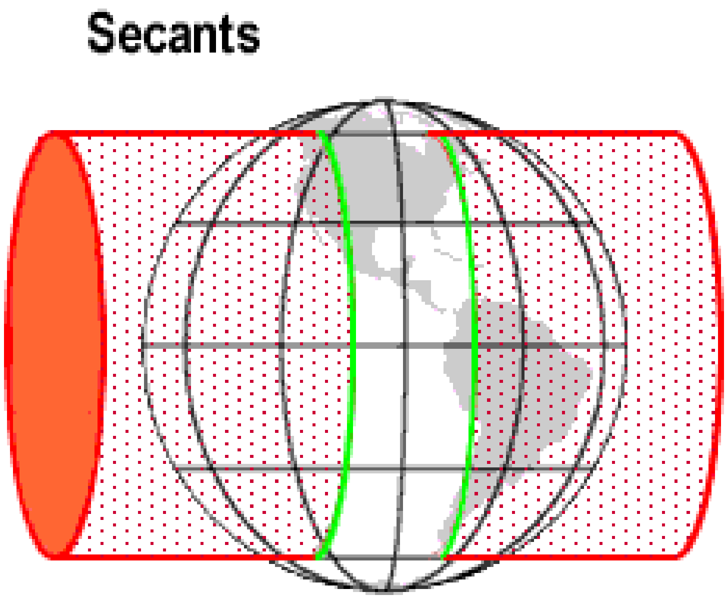
- Zone Names – spelling, punctuation, etc.
- Numerical checks

InGCS Technical Development QA/QC

MAP PROJECTION METHODS: Transverse Mercator – Best suited for InGCS zones

- North-south vs. east-west length (most InGCS Zones)
- Same as current State Plane in Indiana
- Best to not mix projection types
  - Would create opportunity for confusion
  - Only marginally better (if at all)



InGCS Technical Development QA/QC

SCALE FACTOR ANALYSIS

- Selected 5 points per county (corners & middle)
- Tested with Lat, Lon & Elev. from mapping data (+/-10 foot accuracy)
- Tested each point again with high & low elevations for the county – worst case scenario
- Worst distortion found was 28 ppm in “worst case scenario”
- Using “real” locations & elevations 25 of 460 (5.4%) points failed the 10 ppm threshold

InGCS Technical Development QA/QC

SCALE FACTOR ANALYSIS

Table No. 1
Scale Factor Analysis

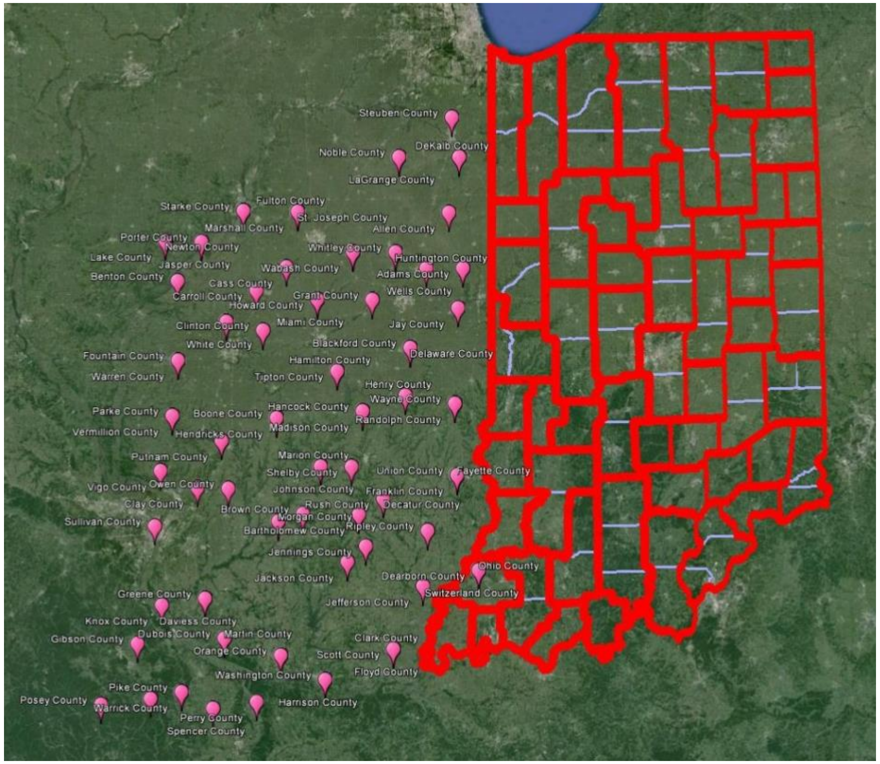
County	CSF (True Elev.)	PPM (True Elev.)	CSF (Low Elev.)	PPM (Low Elev.)	CSF (High Elev.)	PPM (High Elev.)	Location
Adams Co.	1.000005691	5.7	1.000000198	0.2	1.000007422	7.4	Adams Co. SW
	1.000005129	5.1	0.999999492	0.5	1.000006716	6.7	Adams Co. SE
	1.000002595	2.6	0.999999544	0.5	1.000006767	6.8	Adams Co. NE
	1.000003076	3.1	1.000000073	0.1	1.000007296	7.3	Adams Co. NW
	1.000005401	5.4	1.000001392	1.4	1.000008616	8.6	Adams Co. Center
Allen Co.	1.00000003	0.0	0.999995113	4.9	1.000005303	5.3	Allen Co. SW
	1.000002233	2.2	0.999996885	3.1	1.000007075	7.1	Allen Co. SE
	1.000000698	0.7	0.999996931	3.1	1.000007121	7.1	Allen Co. NE
	1.000006427	6.4	0.999996441	3.6	1.000006631	6.6	Allen Co. NW
	1.000006441	6.4	1.000002146	2.1	1.000012336	12.3	Allen Co. Center
Bartholomew Co.	1.000003046	3.0	0.999995777	4.2	1.000017114	17.1	Bartholomew Co. SW
	1.000006226	6.2	0.999998144	1.9	1.000019481	19.5	Bartholomew Co. SE
	1.000009887	9.9	0.999998075	1.9	1.000019412	19.4	Bartholomew Co. NE
	1.000007413	7.4	0.999995554	4.4	1.00001689	16.9	Bartholomew Co. NW
	1.000006045	6.0	1.000000452	0.5	1.000021789	21.8	Bartholomew Co. Center
Benton Co.	1.000002224	2.2	0.999998074	1.9	1.000009795	9.8	Benton Co. SW
	1.000001117	1.1	0.999998832	1.2	1.000010553	10.6	Benton Co. SE
	1.00000245	2.5	0.999998971	1.0	1.000010692	10.7	Benton Co. NE
	1.000000199	0.2	0.999998108	1.9	1.000009829	9.8	Benton Co. NW
	1.000009694	9.7	1.000002579	2.6	1.0000143	14.3	Benton Co. Center

InGCS Technical Development QA/QC

Central Meridian & Latitude of Origin (False Northing & Easting Definition)

Mapped Locations &
Compared to Zone Locations

- Central Meridian/Latitude of Origin
- Origin point of false Northing/Easting



InGCS Technical Development QA/QC

VALIDATION POINT COORDINATES

Check validation point coordinates

Same coordinate for all zones (42° North 85° West)

Compared using 3 different software packages

- Trimble Business Center
- MicroSurvey Star*Net
- Topcon Magnet Tools

No differences of more than 0.001 m were found between the 3 software packages.

InGCS Technical Development QA/QC

VALIDATION POINT COORDINATES

No differences of more than 0.001 m were found between the 3 software packages.

Indiana Geospatial Coordinate System (InGCS)

Validation Point: Multi-Vendor Coordinate Computations

The following grid coordinates were computed by the corresponding software programs and versions thereof. The computations involved converting a single, common position of latitude and longitude of **42° North** and **85° West** (per NAD 83) to the grid coordinates (in meters) of the appropriate Indiana Geospatial Coordinate System (InGCS) Zone. The purpose of this exercise was to provide QC/QA for the values of the Validation Points as published in the InGCS definitions file by comparing them to the values as computed by different proprietary geospatial software providers. The values published in the InGCS definitions file were derived from MicroSurvey Star*Net Version 7.2.

GEODETIC DATUM: NAD 83

Zone Name	MicroSurvey Star*Net Version 7.2		Trimble Business Center Version 3.40		Topcon Magnet Tools Version 1.2.1	
	Easting (X) (meters)	Northing (Y) (meters)	Easting (X) (meters)	Northing (Y) (meters)	Easting (X) (meters)	Northing (Y) (meters)
Adams County	235,857.321	197,042.576	235,857.321	197,042.576	235,857.321	197,042.576
Allen County	244,142.667	158,173.879	244,142.667	158,173.879	244,142.667	158,173.879
Bartholomew County	310,425.254	369,491.117	310,425.254	369,491.117	310,425.254	369,491.117
Benton County	430,567.721	210,705.421	430,567.721	210,705.422	430,567.721	210,705.422
Blackford County	273,141.593	252,641.732	273,141.593	252,641.733	273,141.593	252,641.732
Boone County	364,282.128	303,618.467	364,282.128	303,618.467	364,282.128	303,618.467
Brown County	347,710.206	369,960.596	347,710.206	369,960.596	347,710.206	369,960.596
Carroll County	376,709.323	215,014.436	376,709.323	215,014.436	376,709.323	215,014.436

InGCS Technical Development QA/QC

ZONE DEFINTIONS AND NAMES

Zone groupings were reviewed and checked for possible additional combinations.

No additional combinations were recommended.

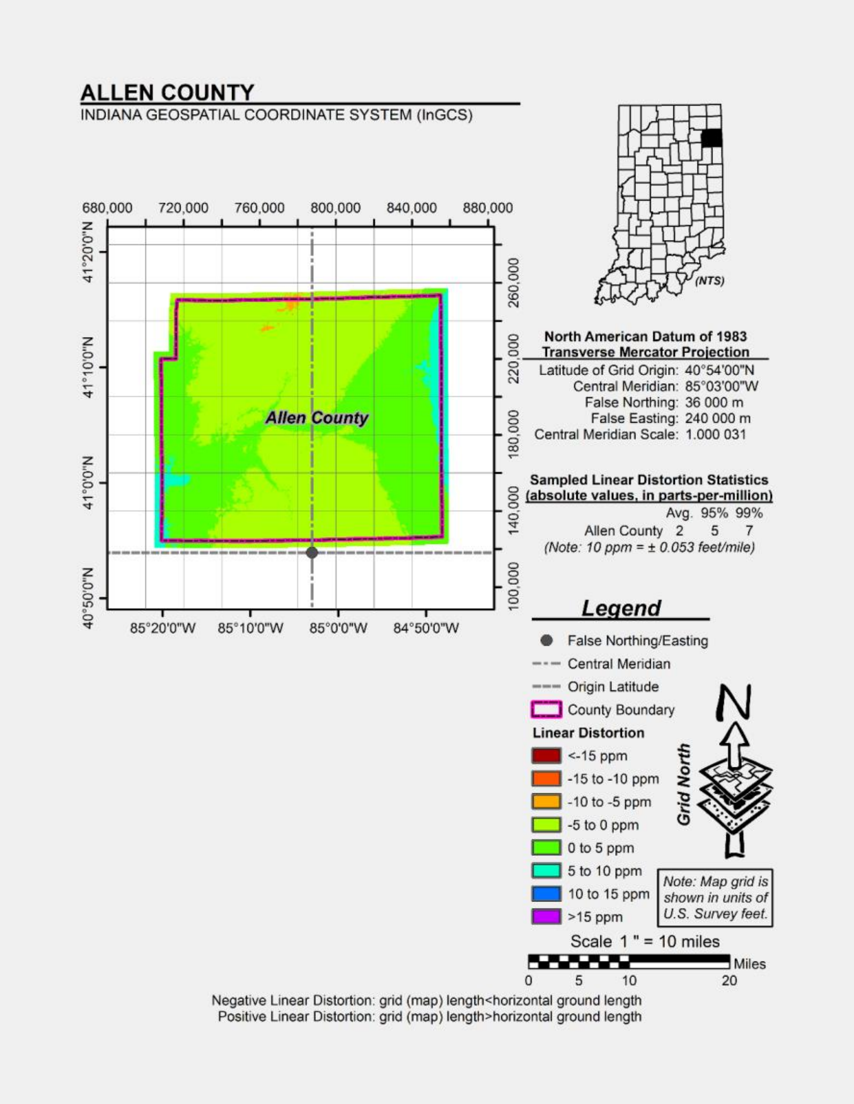
Zone names were check for spelling.

InGCS Technical Development QA/QC

NUMERICAL CHECKS

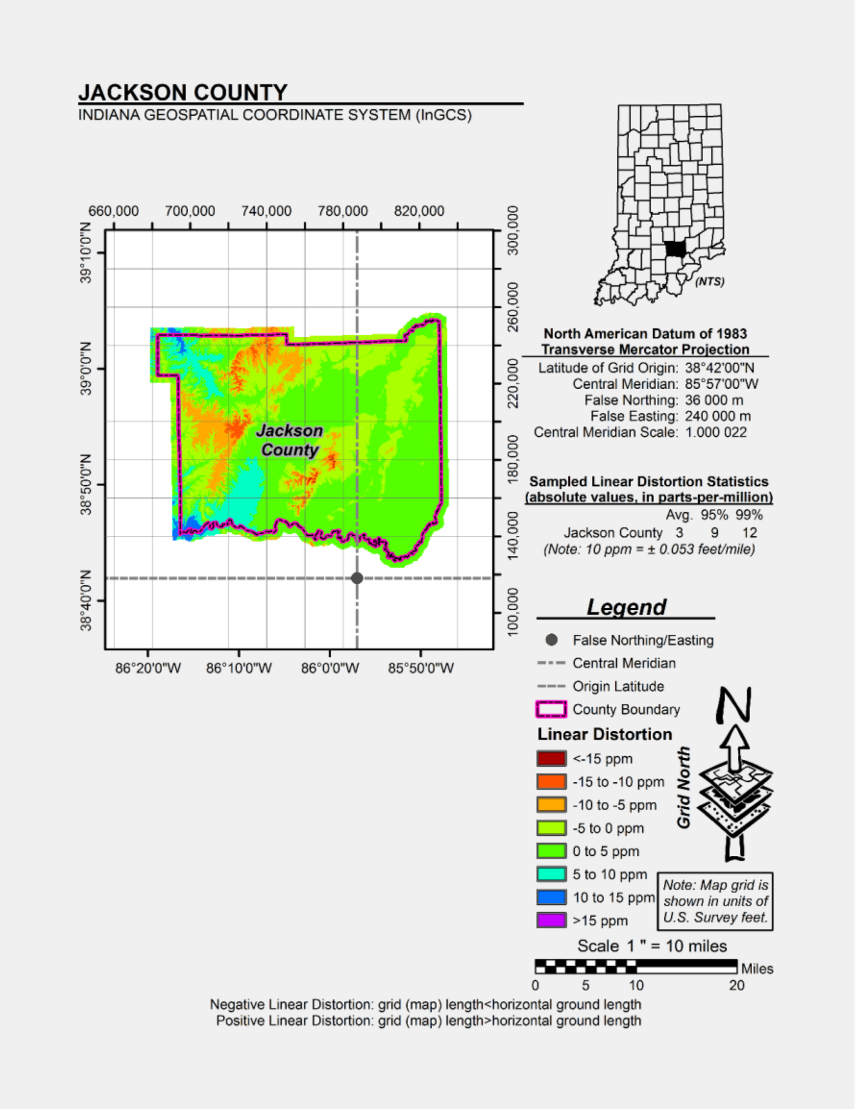
- 85 degrees 24 minutes was converted to 84.40 degrees (should be 85.40 degrees) on page 49 (Blackford County). – Revised and checked 3/12/15
- The Central Meridian and CM Scale Factor listed on page 55 (Clay County) does not match the listing in the table on page 147. The table on page 147 lists the Central Meridian and CM Scale Factor of Alternate 2, which was not the approved alternate. The Alternate 2 Central Meridian and CM Scale Factor were used by Lochmueller Group to compute the validation point coordinates using Trimble Business Center and MicroSurvey Star*Net on page 147, also. – Revised and checked 3/12/15
- 85 degrees 42 minutes was converted to 85.75 degrees (should be 85.70 degrees) on page 71 (Grant County). – Revised and checked 3/12/15
- 85 degrees 27 minutes was converted to 84.45 degrees (should be 85.45 degrees) on page 88 (LaGrange County). – Revised and checked 3/12/15
- 85 degrees 27 minutes was converted to 84.45 degrees (should be 85.45 degrees) on page 101 (Noble County). – Revised and checked 3/12/15

InGCS: Example Single-County Zone



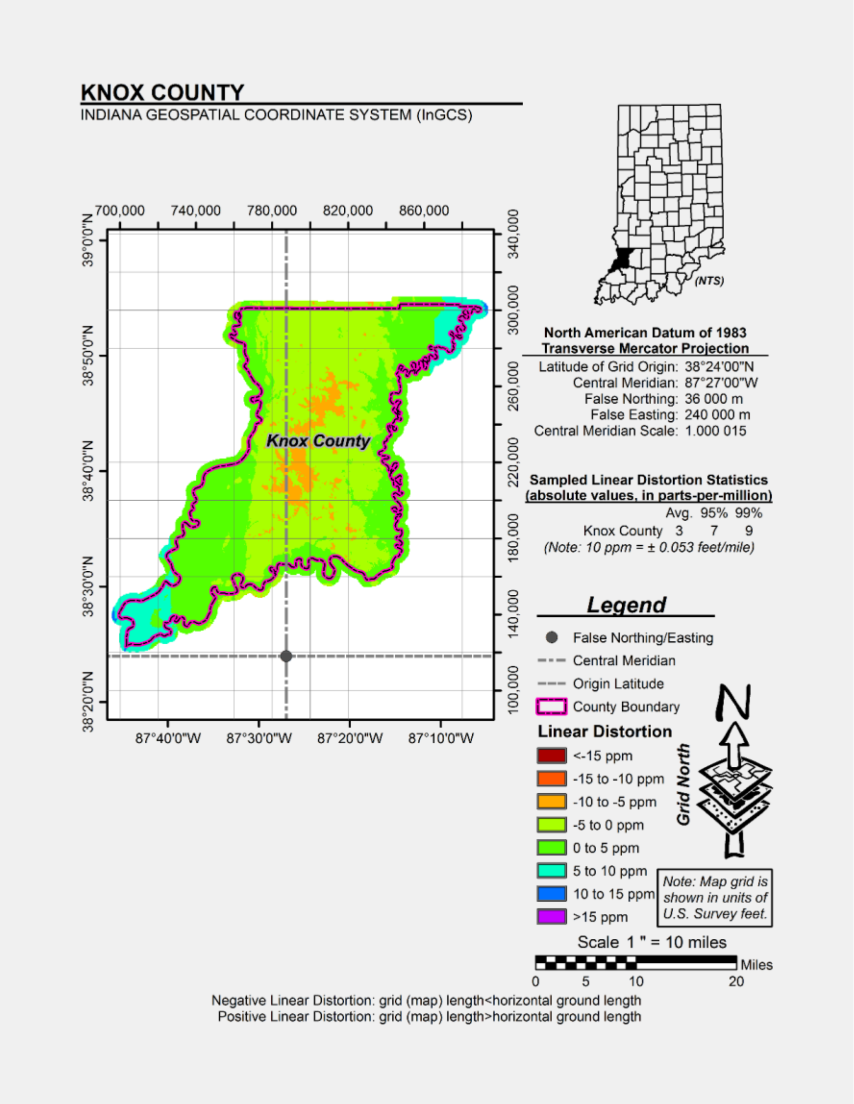
Indiana Geospatial Coordinate System (InGCS)

InGCS: Example Single-County Zone



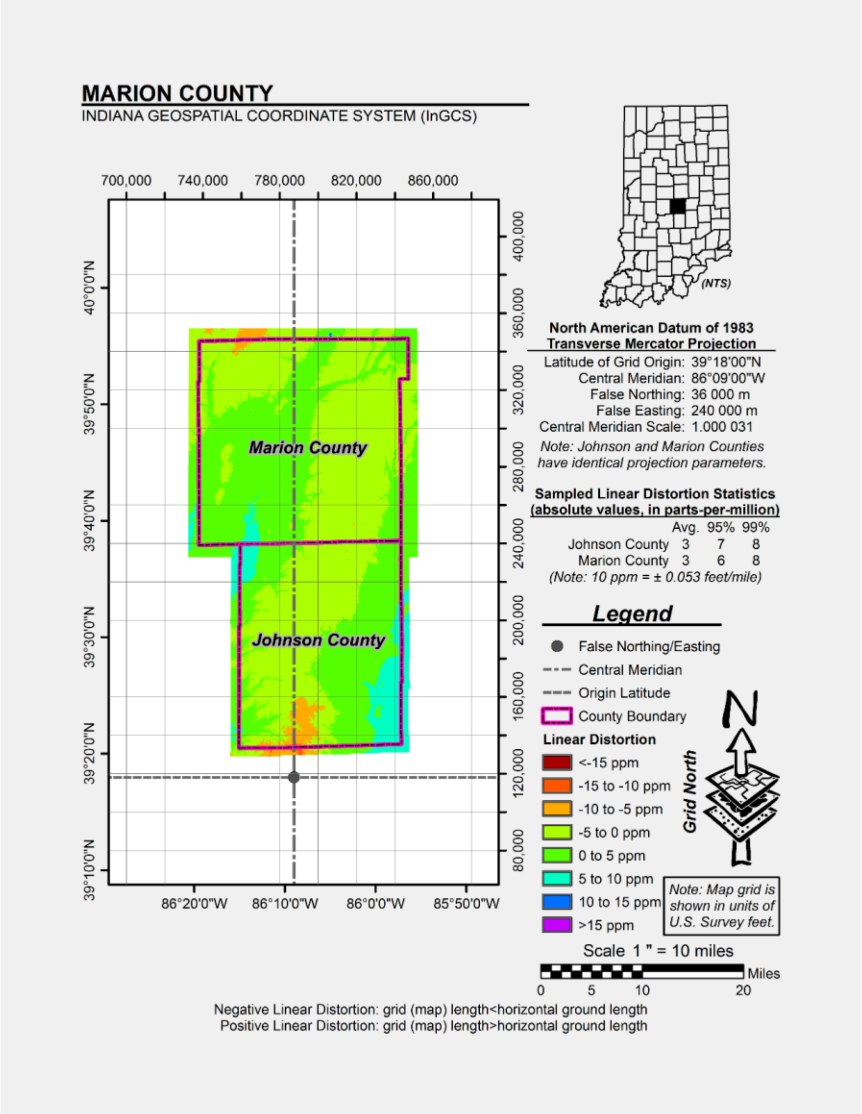
Indiana Geospatial Coordinate System (InGCS)

InGCS: Example Single-County Zone



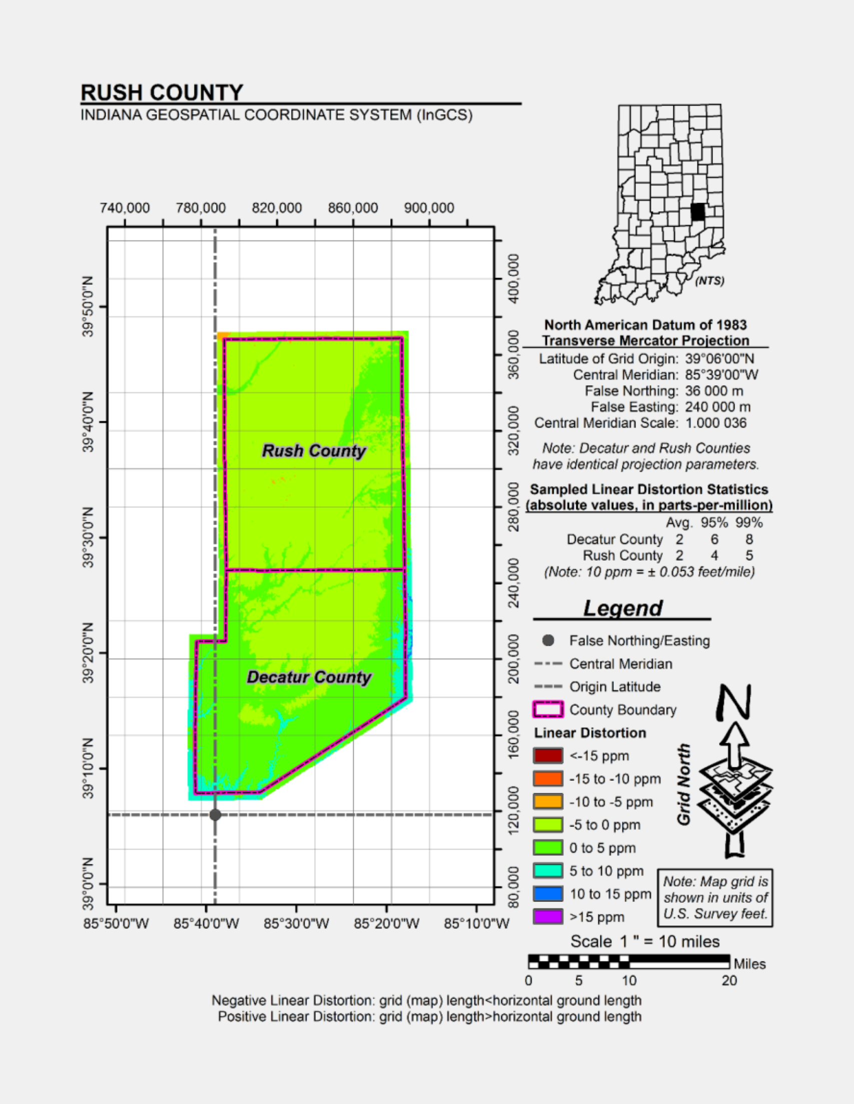
Indiana Geospatial Coordinate System (InGCS)

InGCS: Example Double-County Zone

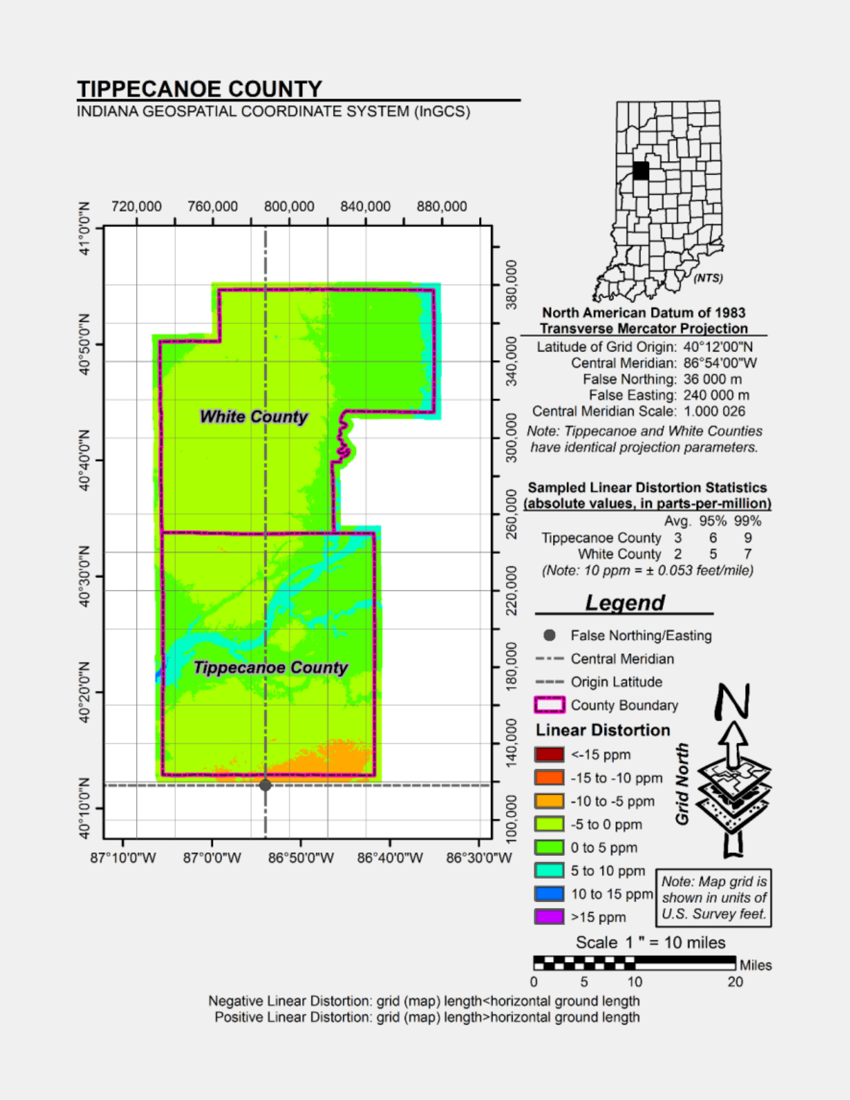


Indiana Geospatial Coordinate System (InGCS)

InGCS: Example Double-County Zone

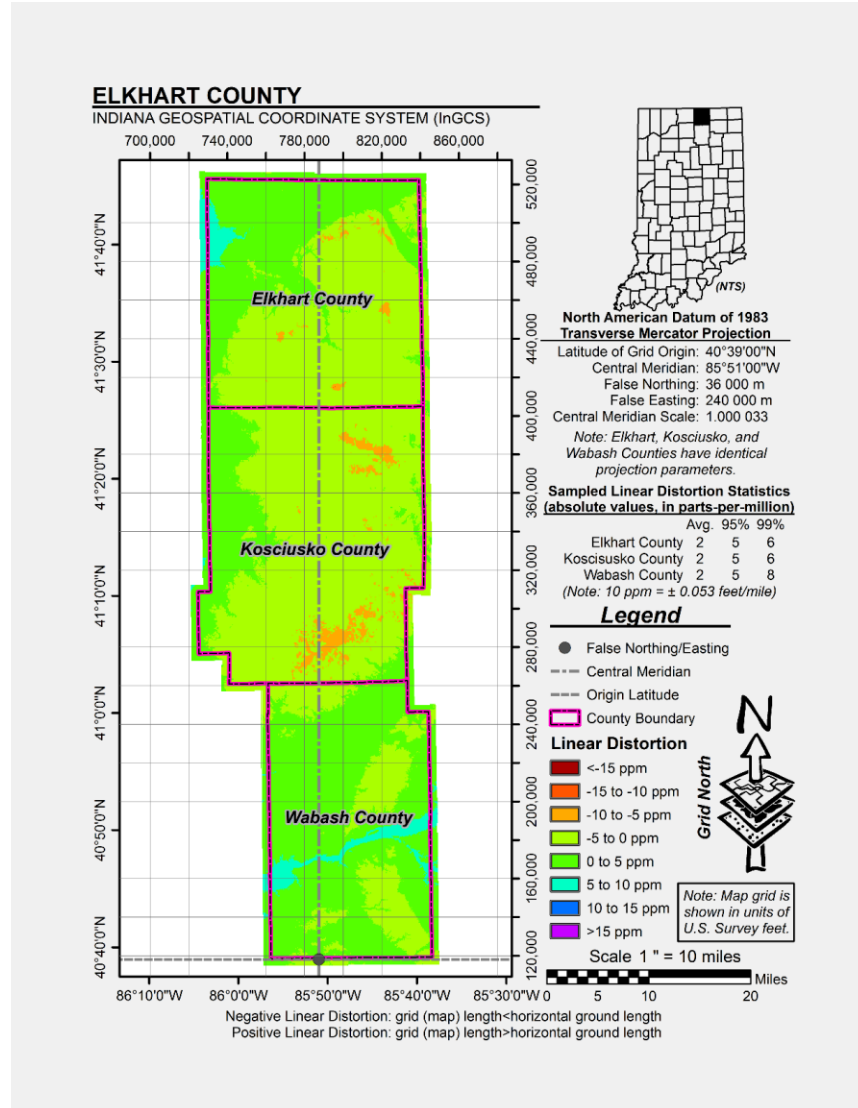


InGCS: Example Double-County Zone

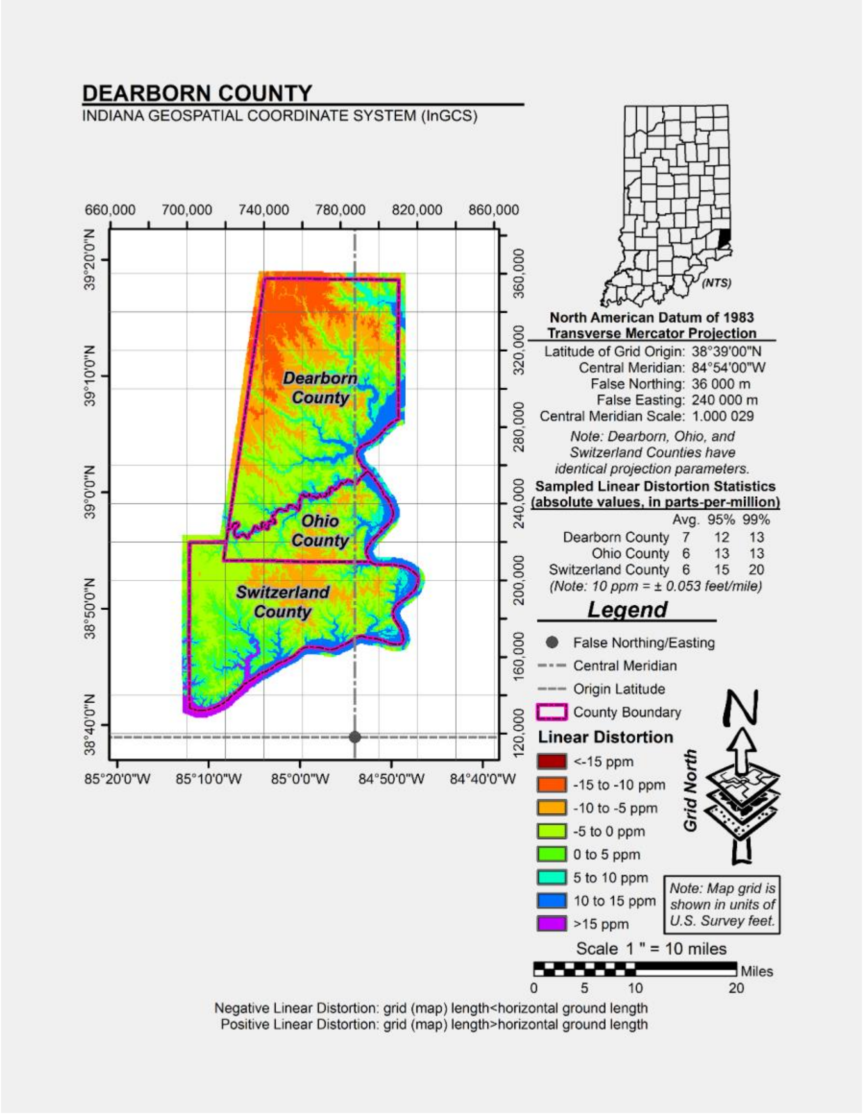


Indiana Geospatial Coordinate System (InGCS)

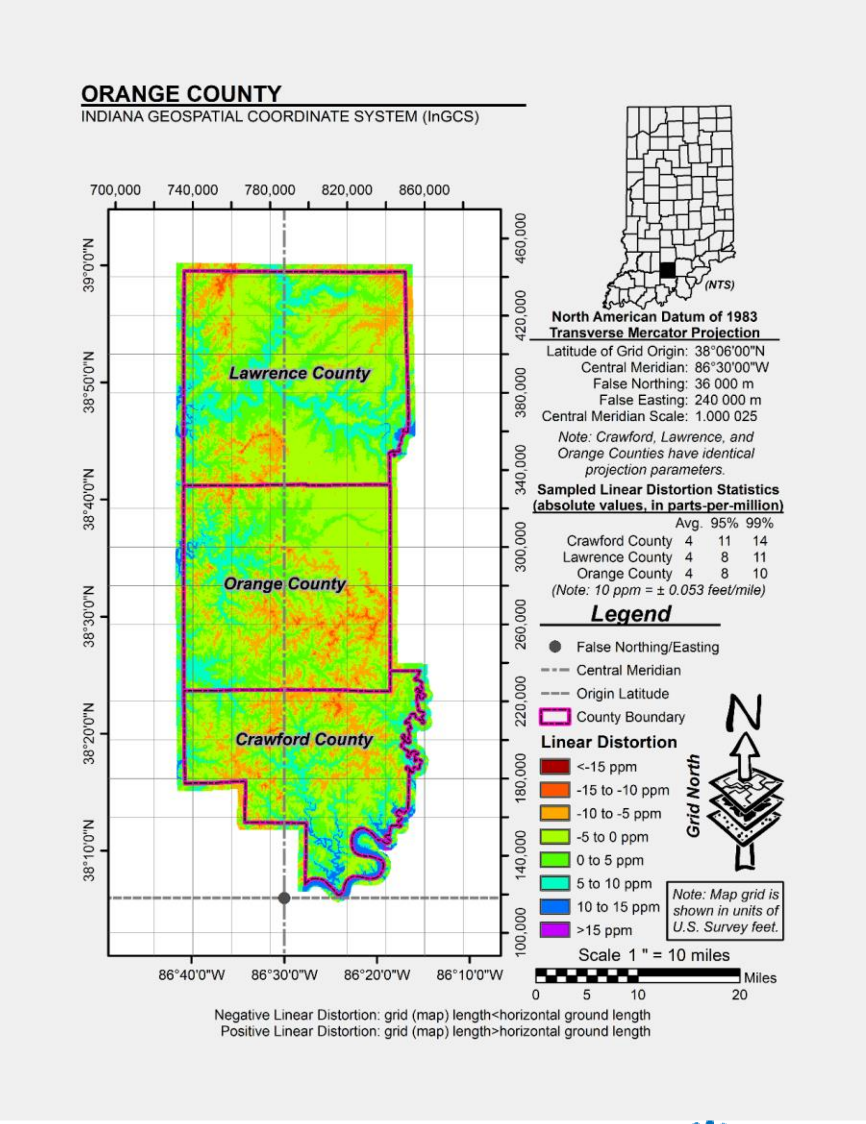
InGCS: Example Triple-County Zone



InGCS: Example Triple-County Zone



InGCS: Example Triple-County Zone



InGCS: Recommended Guidelines

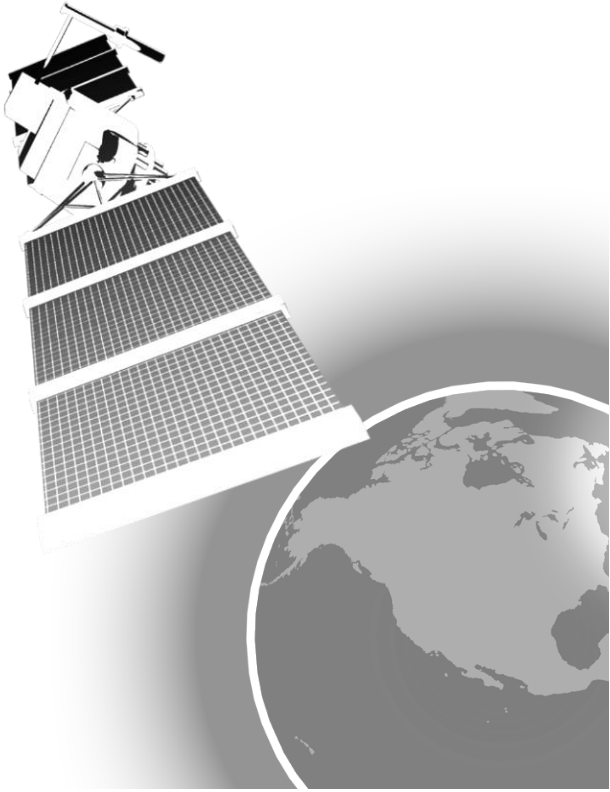
- Position relative to the NSRS
  - NAD 83(2011) epoch 2010.00 is the most current realization of NAD 83
  - NGS' CORS is the foundation of the NSRS (OPUS Projects, OPUS, OPUS-RS)
  - NGS Passive Marks
  - Real-Time GNSS Networks (RTNs)…

Indiana Geospatial Coordinate System (InGCS)

“The future of positioning is GNSS.”

“Improving the National Spatial Reference System”
2010 Federal Geospatial Summit

-Dr. Dru Smith, former Chief Geodesist,
current NSRS Modernization Manager, NGS



Real-Time GNSS Networks (RTNs)

As with all positioning methodologies, users are still encouraged to use caution and perform satisfactory checks on KNOWN geodetic control before proceeding with work. Use of RTNs are not an exception.

Real-Time GNSS Networks (RTNs)

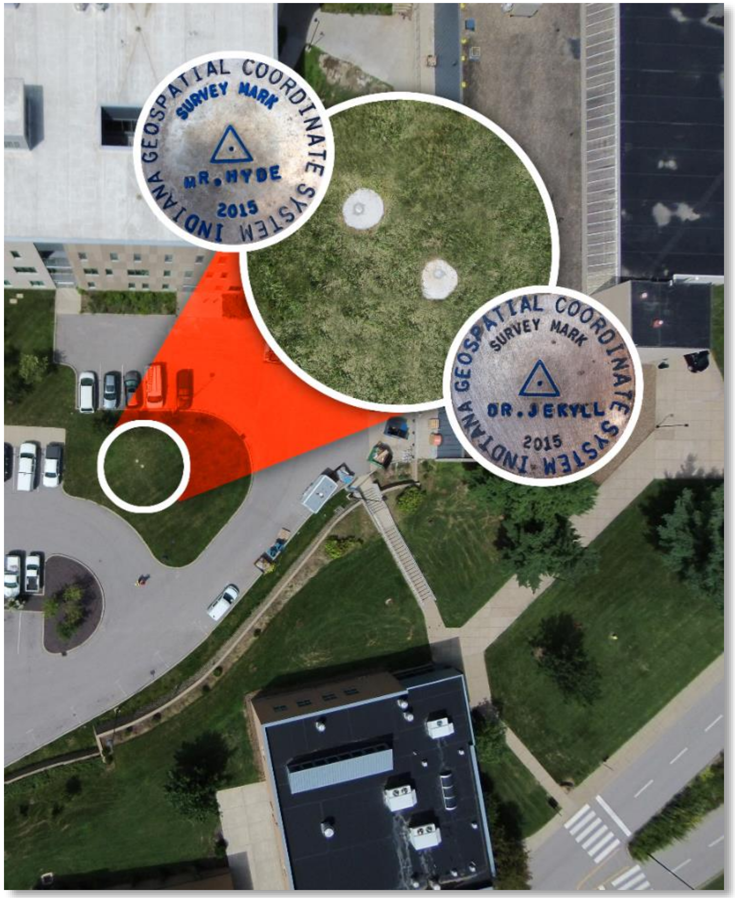
Depending upon what is being broadcast from the RTN provider to the end users and which Geometric Datum the user selects, the software in the GNSS rovers may be positioning the users correctly, or may be "double-correcting" them.

Real-Time GNSS Networks (RTNs)

Example: Given known Indiana State Plane, West zone coordinates on "DR.JEKYLL" from OPUS-DB

Using either INDOT's InCORS or Trimble's VRS Now! RTN and selecting “State Plane 1983 (ITRF to NAD 1983)" in Trimble Access (V2.80) to stake out "DR.JEKYLL" will result in the location of "MR.HYDE" approximately 3-feet to the northwest.

Selecting “US State Plane 1983" will stake out "DR.JEKYLL" within typical RTN-tolerances.



Real-Time GNSS Networks (RTNs)

So if there's a ±3-foot horizontal discrepancy found in a project lying in a northwest or southeast direction, the source may be that of an incorrect selection of the Geometric Datum.

Real-Time GNSS Networks (RTNs)

When working with INDOT's InCORS network, refer to http://incors.in.gov/faq.aspx for recommendations from various software vendors upon which Geometric Datum to select.

Independent tests have shown that selecting a zero transform NAD 83 datum typically provides centimeter-grade horizontal accuracy on marks with known NAD 83(2011) epoch 2010.00 values.

This is true for whichever projected coordinate reference system the user selects, e.g., InGCS, SPCS, UTM.

Real-Time GNSS Networks (RTNs)

The following “Geodetic Datum” statement is included on the InGCS numerical deliverables for, amongst others, geospatial software providers and end users to address the double-correction issue.

GEODETIC DATUM: The Indiana Geospatial Coordinate System (InGCS) is referenced to the latest realization of the National Spatial Reference System (NSRS), which is currently defined geometrically as NAD 83(2011). For projects based upon the InGCS, the burden of identifying the datum tag (realization) in metadata will be upon the practitioner.

For agencies, groups, proprietary geospatial software providers, etc. preparing to include the InGCS in their respective geodetic parameter datasets, coordinate system libraries, etc., it is recommended that they minimally include the current realization of NAD 83, i.e. NAD 83(2011) and any subsequent realizations. Please note that there have been “double-correction” issues in the magnitude of approximately two meters (three-dimensionally) identified with certain commercially available field system's software when using Real Time (GNSS) Networks (RTN) and other projected coordinate systems, such as Stare Plane, when attempting to correctly position respective to NAD 83(2011). End users of the InGCS should measure the success of their proprietary geospatial software by the ability to unambiguously perform geodetic computations and repeatedly observe undisturbed geodetic survey marks published by the National Geodetic Survey bearing NAD 83(2011) (and any future realizations) values within industry-acceptable tolerances for the work being performed, regardless of the global positioning method employed (RTN, RTK, PPP, Static, etc.).

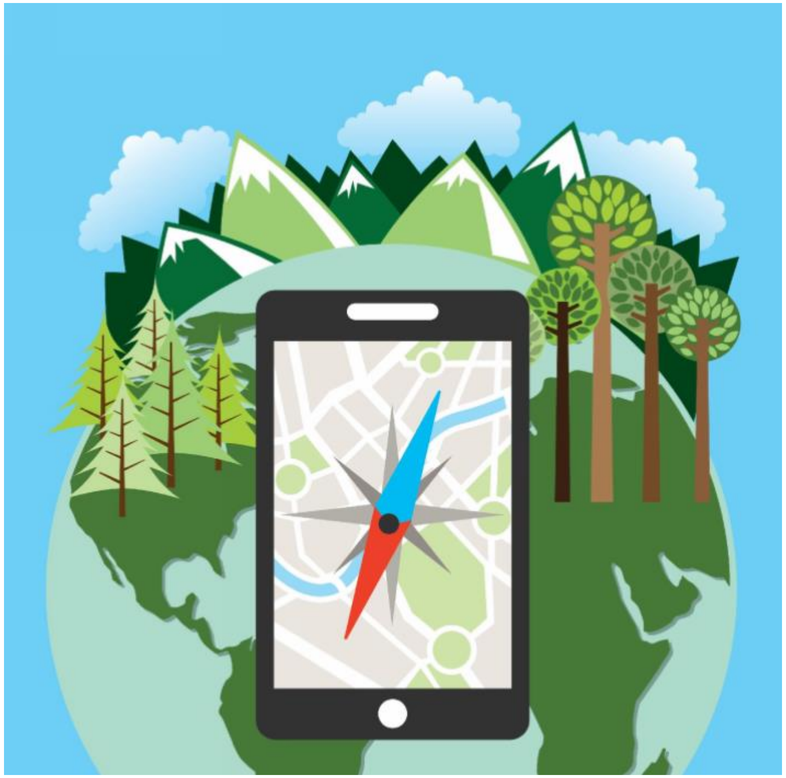
InGCS and Non-Survey-Grade GNSS Receivers

The InGCS (or any other LDP system) does not "boost" the accuracy of any GNSS receiver.

Sub-meter units will not achieve centimeter-grade accuracy by uploading the InGCS.

Centimeter-grade GNSS receivers will not achieve millimeter-grade accuracy.

But they all can "map" to the InGCS.



InGCS: Recommended Guidelines

- Working Units: U.S. Survey Feet
- Total Stations
  - PPMs: Be sure to NOT double correct for atmospheric conditions
    - Check with your vendor
    - Visit a CBL to validate Total Station and Data Collector settings and prism offsets

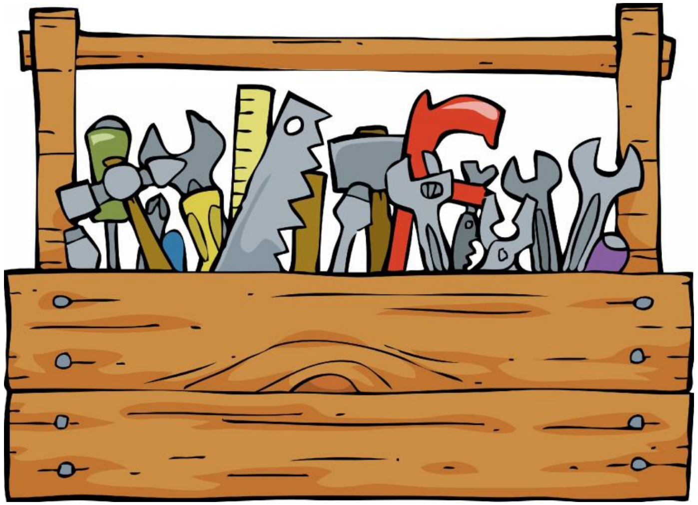
InGCS: Recommended Guidelines

- Surveyor’s Reports & Basis of Bearing
  - To be included in the revised INDOT Design manual and the InGCS Handbook and User Guide
- Boundary Surveying…

InGCS and Boundary Surveying

How does the InGCS help the boundary surveyor?

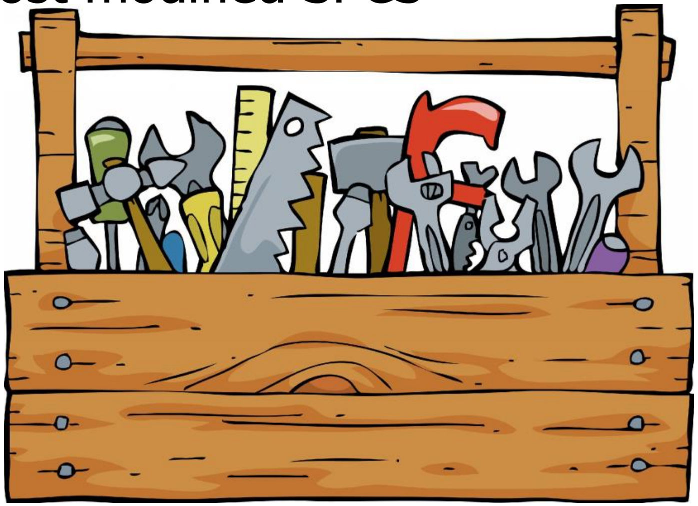
To the boundary surveyor, the InGCS is a great addition to all the tools in the toolbox.



InGCS and Boundary Surveying

Amongst other things, the boundary surveyor can use the InGCS to:

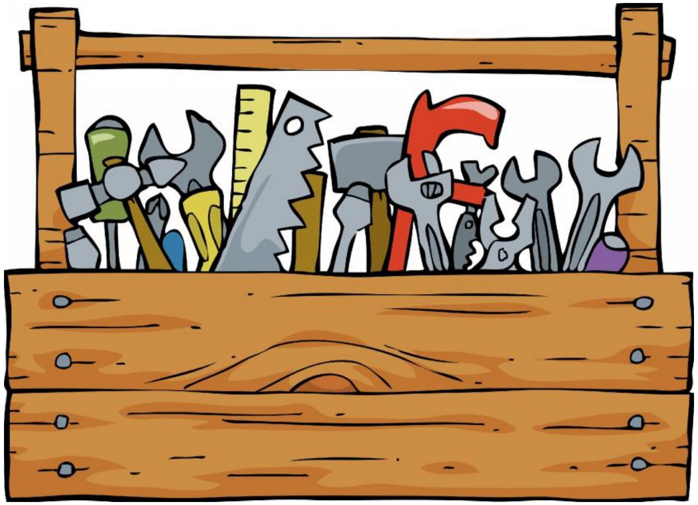
- Analyze field recon data with grid distances that are considerably closer to ground-measured horizontal distances than UTM or SPCS
- Tie larger regions of surveys together while maintaining minimal "grid vs. ground" differences than with most modified SPCS
- Submit plats and/or electronic drawings to clients and/or public agencies (LPA, INDOT, etc.) with properly georeferenced **project coordinates** considerably closer to ground-measured horizontal distances than with SPCS
- Etc., etc.



InGCS and Boundary Surveying

BUT, the InGCS does not relieve the boundary surveyor from performing the tasks involved with properly performing boundary surveys, i.e.:

- Public records research
- Evaluation of recorded documents
- Field reconnaissance
- Analyzing field evidence
- Applying proper principles to arrive at prudent decisions
- Etc., etc.



InGCS and Boundary Surveying

A general summary of the priority in the rules of authority/construction in boundary control:

- Unwritten rights
- Senior rights
- Written Intentions of Parties
    - Call for a Survey
    - Call for a Monument
        - natural, artificial, record
    - Distance
    - Direction
    - Area
    - Coordinates

InGCS and Boundary Surveying

The bottom four (distance, direction, area, coordinates) relate most closely to measurements and byproducts of those measurements (area and coordinates).

So what does this mean for the InGCS?

InGCS and Boundary Surveying

This does not have an impact on the InGCS itself, but it does keep us (the boundary surveyors) in check so as to not let current or future measurement technology give us a false sense of overconfidence in digital data over the intent of the parties, controlling calls in deeds, physical monuments, etc.

Latitude=N 43°53’57.678452278”
Longitude=W 98°17’41.226045337”

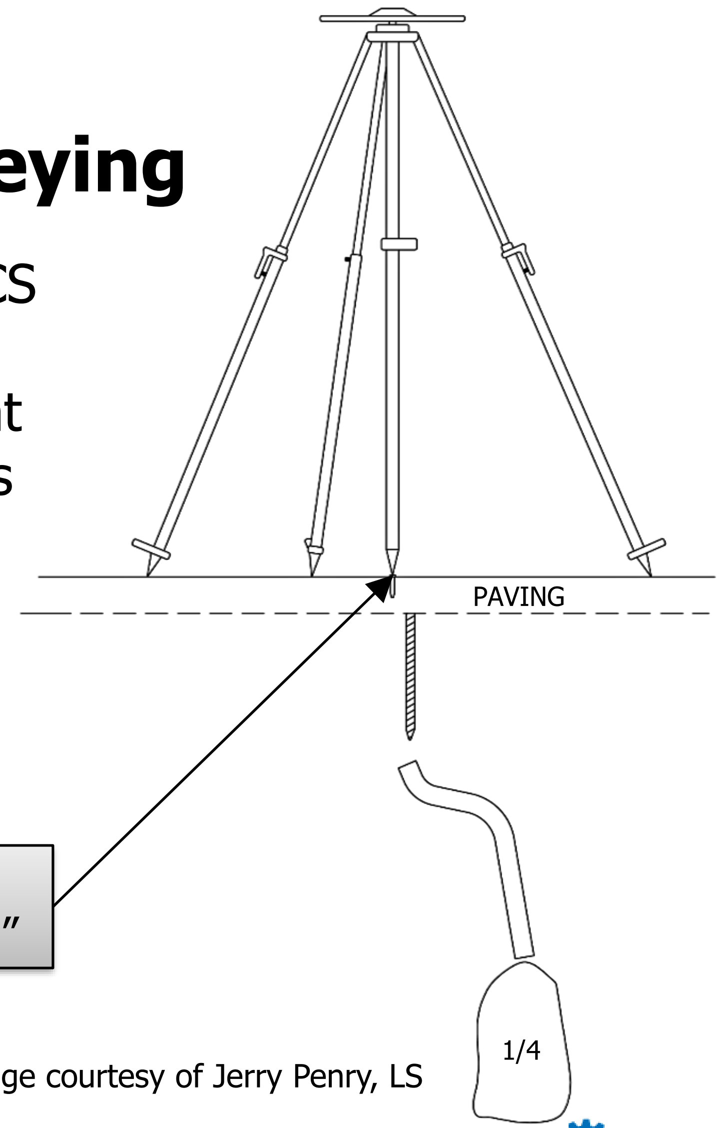


Image courtesy of Jerry Penry, LS

InGCS: Recommended Guidelines

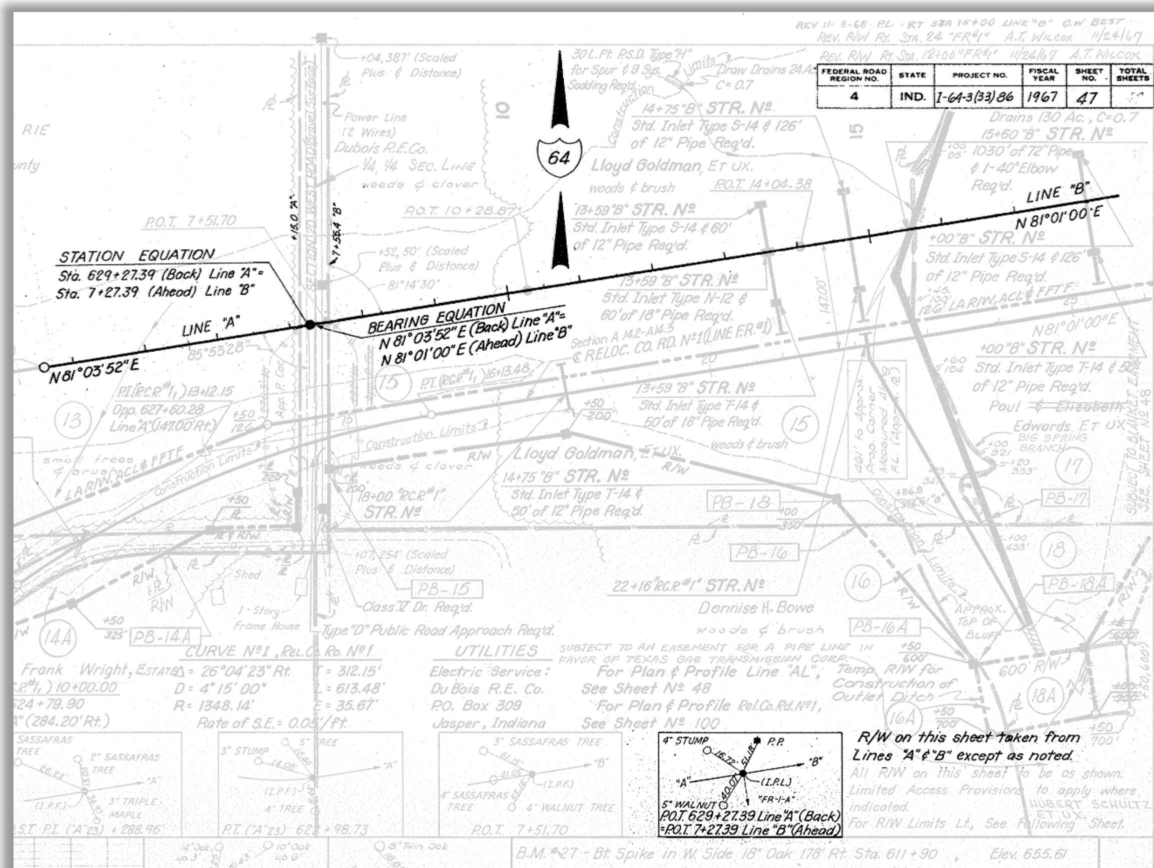
- Projects crossing into a new zone with different grid coordinates…

Indiana Geospatial Coordinate System (InGCS)

Projects Spanning Across InGCS Zones

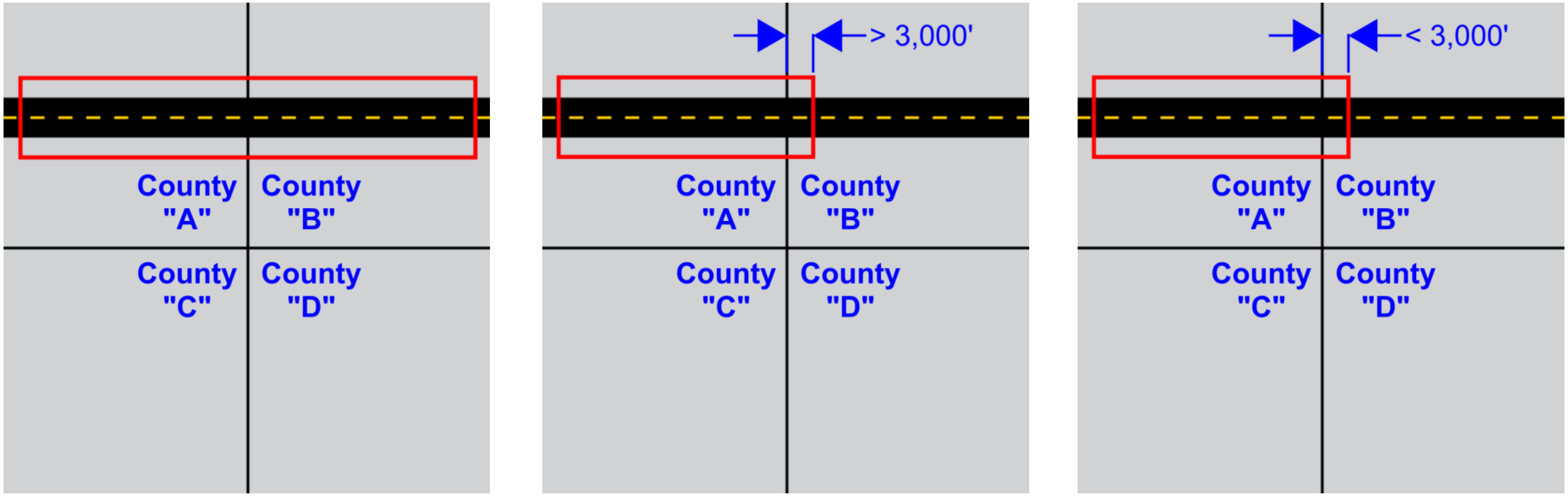
The act of projects crossing into a different "coordinate system" is by no means new to practitioners.

Consider how both the "Station Equation" and "Bearing Equation" in this example I-64 plat from 1967 impacted calculations.



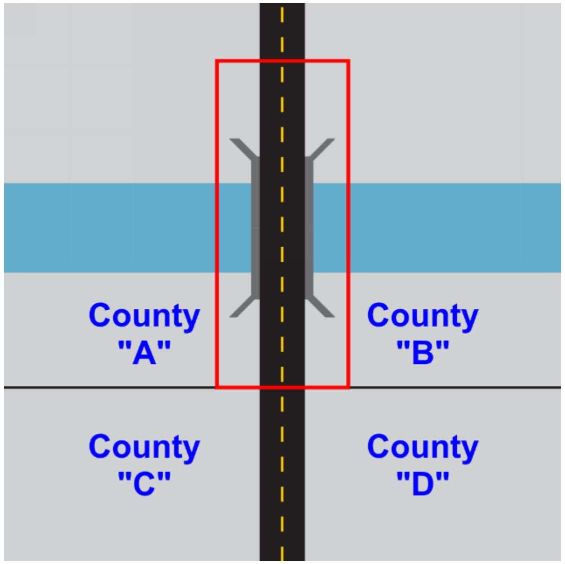
Projects Spanning Across InGCS Zones

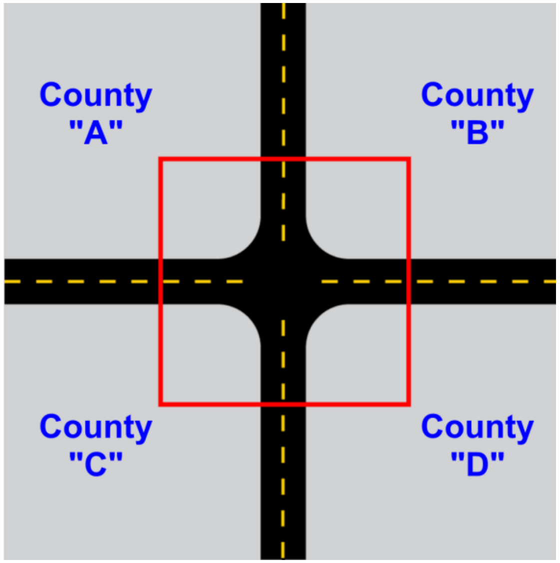
The InGCS Handbook and User Guide and the revised INDOT Design Manual will have more in-depth recommendations on projects spanning across InGCS zones, but the following six general instances are to be considered. The red polygons represent the approximate project limits in each instance.

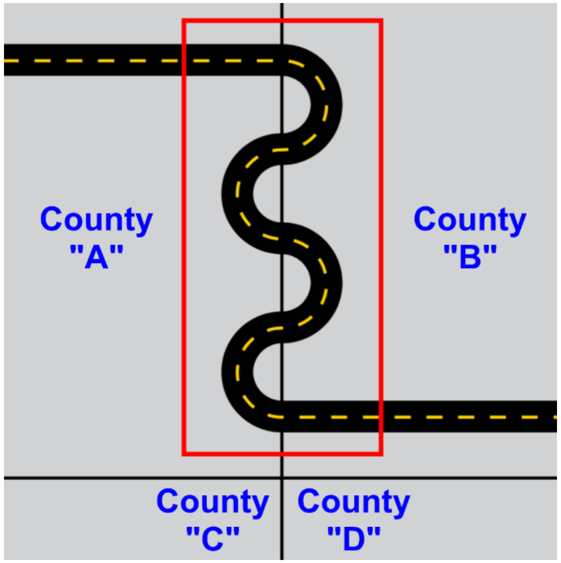


Projects Spanning Across InGCS Zones

As there are a seemingly infinite number of different scenarios for projects crossing zone lines, the approaches provided should not be meant as strict rules, but as guidelines. Instances may arise where more logical solutions could be offered that would be contrary to the provided guidelines.







Projects Spanning Across InGCS Zones

- Grid Coordinate Conversions
  - Many geospatial software platforms offer embedded coordinate system conversions. Check with your vendor!

NGS Station: HATFIELD

Geometric Datum: NAD 83(2011) epoch 2010.00

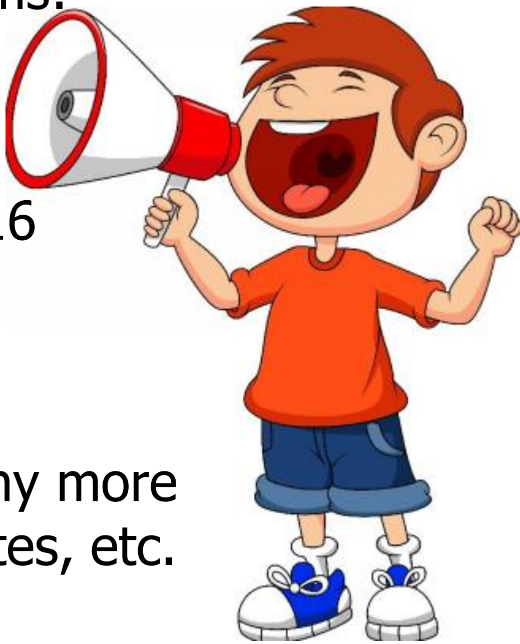
Lat/Long:	37°54'11.18210"(N)	87°14'32.43551"(W)
UTM 16:	N 13,763,398.369	E 1,570,518.298
IN SPCS, West:	N 967,030.604	E 2,906,870.427
InGCS, Spencer:	N 173,921.638	E 731,900.029
InGCS, Warrick:	N 137,454.207	E 804,036.683

InGCS: Availability

An InGCS release announcement was sent to geospatial software vendors in 2015, giving them the URL for the InGCS parameters.

The InGCS is currently available in the following systems:

- EPSG's Geodetic Parameter Dataset
- Trimble Business Center (Version 3.61)
- Blue Marble Geographics-Geographic Calculator 2016
- Esri ArcMap 10.4
- ???



It is anticipated that the InGCS will be available in many more platforms in their Spring 2016 releases, patches, updates, etc.

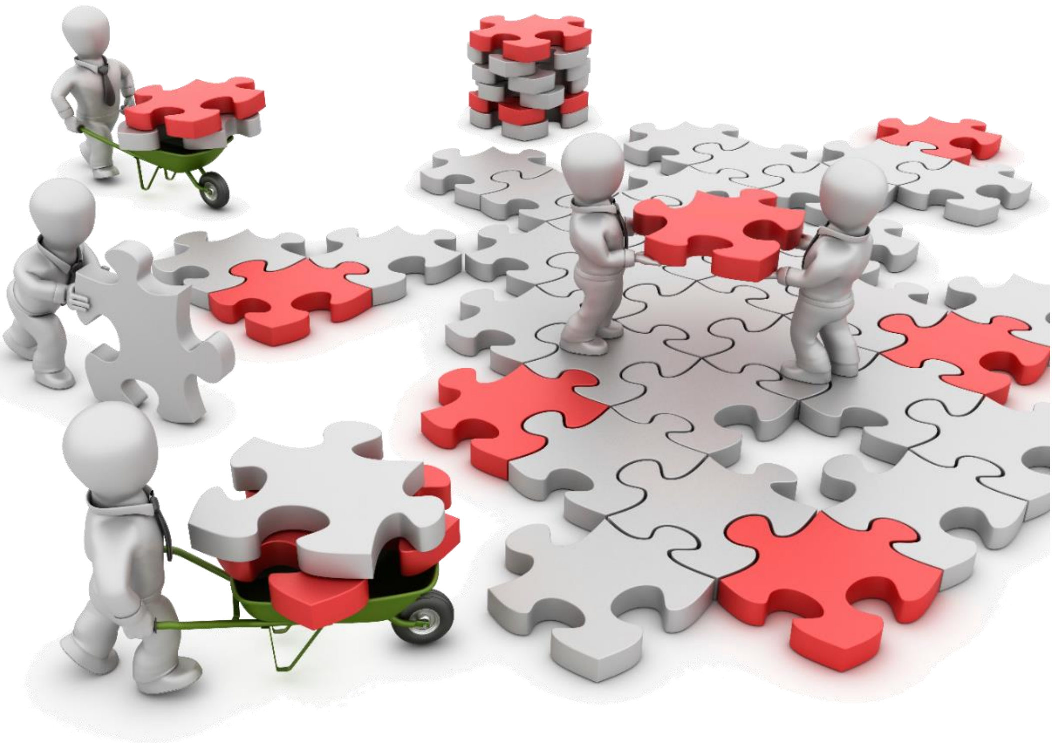
What's next???

INDOT is working towards the following roll-out of the InGCS:

- Writing a "Handbook and User Guide"
- Rewriting the appropriate Sections of the INDOT Design Manual
- Seminars, workshops, conferences, etc.

InGCS: Executive Summary

The InGCS endeavor has set the stage for a far more efficient workflow between planning, surveying, design, construction, GIS, and other industries within the geospatial community.



InGCS: Webpage

For more information coming in the future, please refer to INDOT’s Land & Aerial Survey Office’s webpage

- https://in.gov/indot/2715

As well the InGCS’ webpage

- http://www.in.gov/indot/InGCS.htm (case sensitive)

Questions?