Esri International Developer Summit

Palm Springs, CA

Understanding and Using Geometry, Projections and Spatial Reference Systems in ArcGIS

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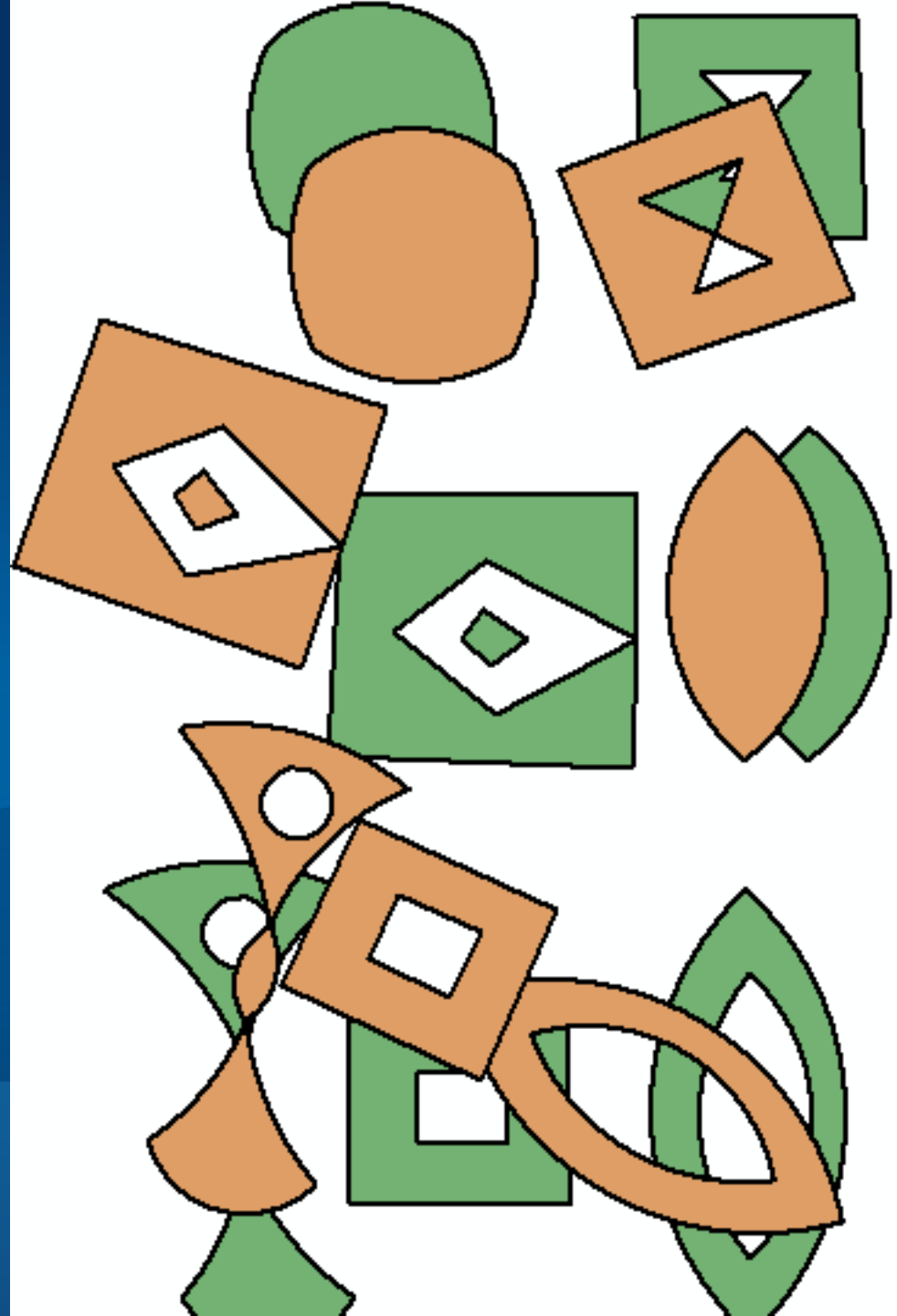
Introduction

We present fundamental concepts necessary for the correct and efficient use of geometry and spatial reference APIs

- Geometry types
- Spatial references and their properties
- How spatial references and geometries interact

Geometry



What is a geometry?

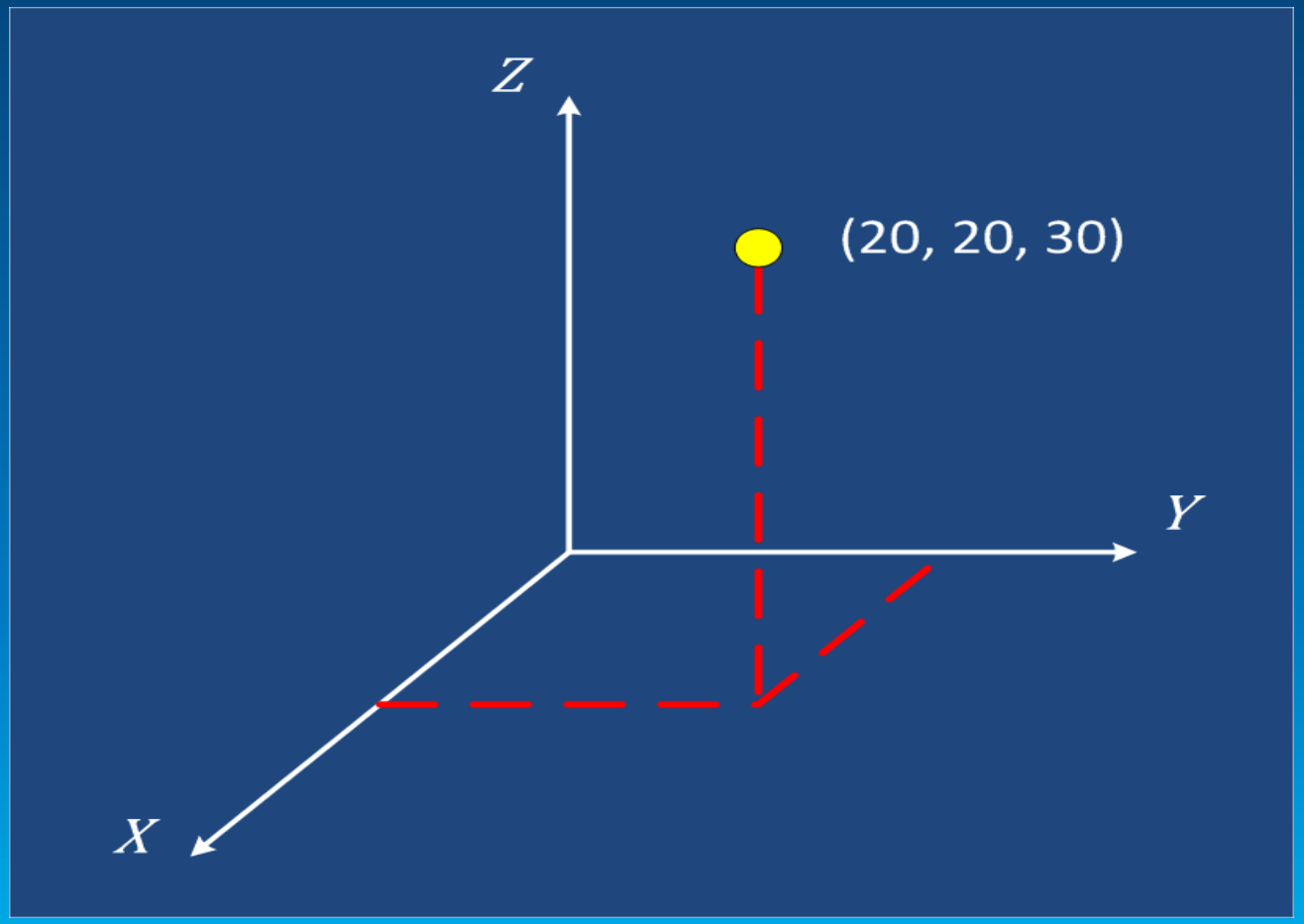
- Defines the shape of a feature
- Vector representation for top level types
  In other words, vertices have x, y coordinates
- Optional z- (height) and m- (measure)

Working with and analyzing geometries

- **Simple geometry verification**
  - **Adhere to a set of rules**
- **Topological operations**
  - **For example, Buffer, Symmetric Difference, Union, Intersection**
- **Relational operations**
  - **For example, Disjoint, Touches, Overlaps, Crosses, Within**

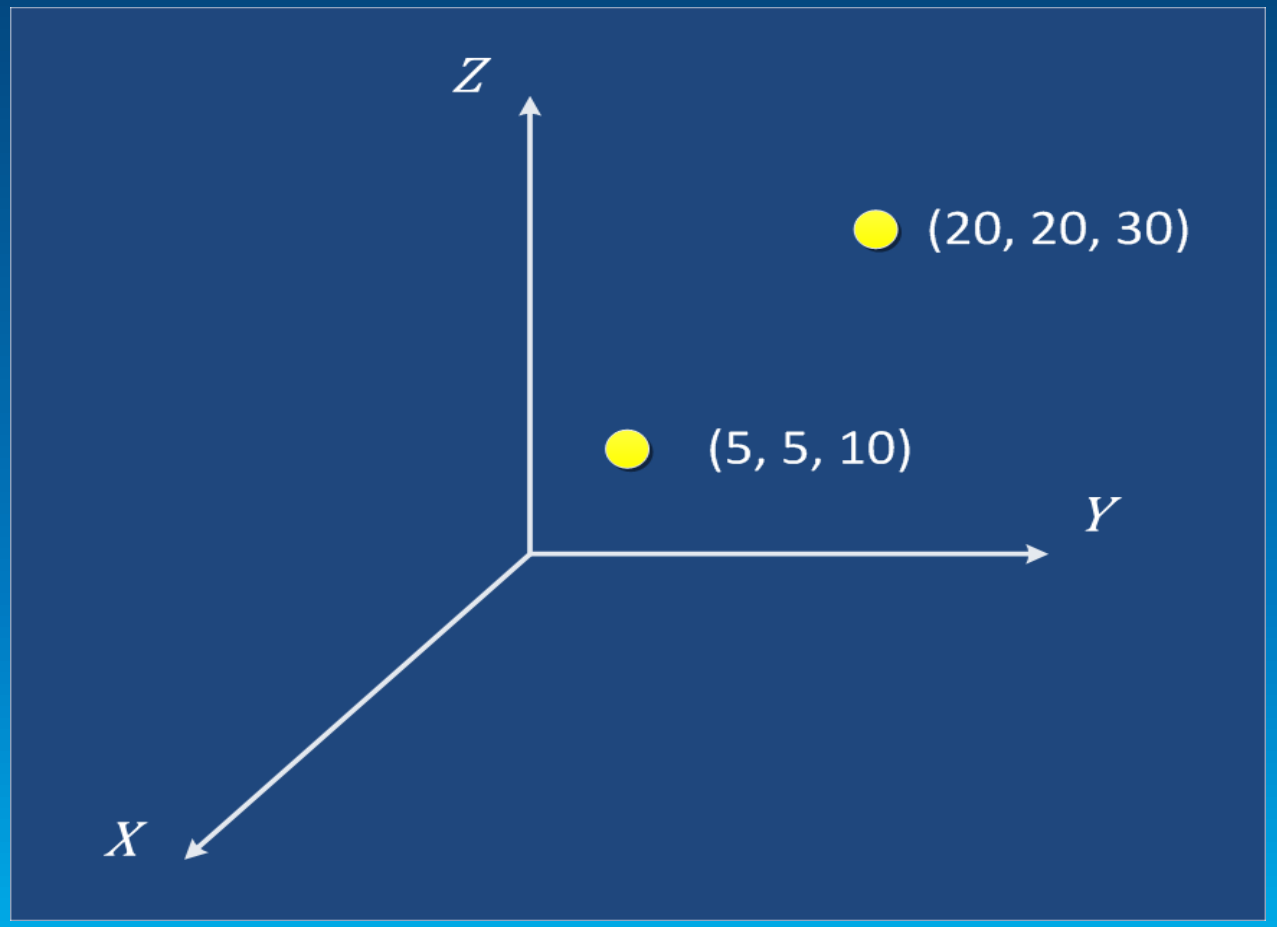
Points

Building blocks for all geometries



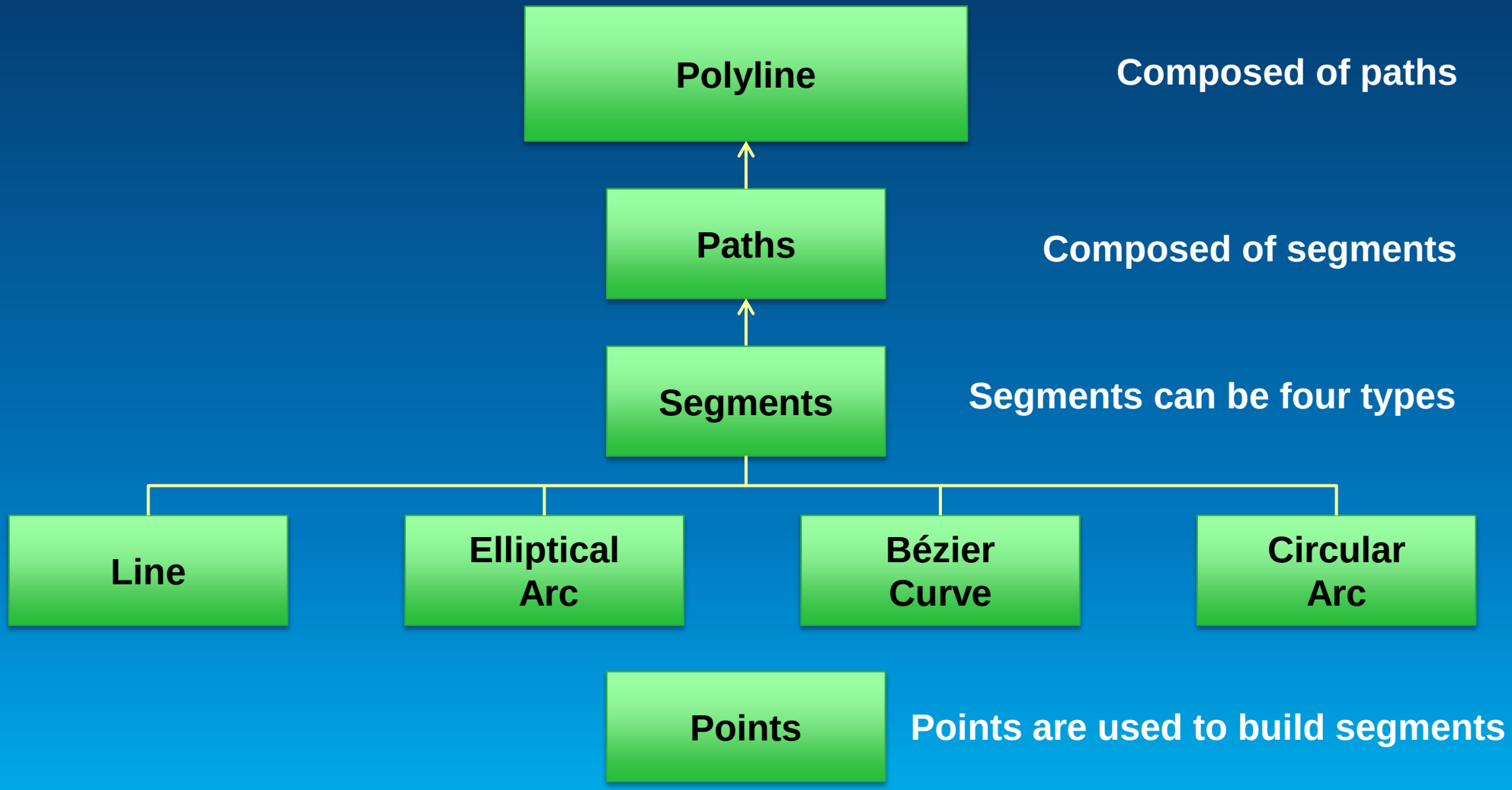
Multipoints

Each multipoint feature is a collection of points

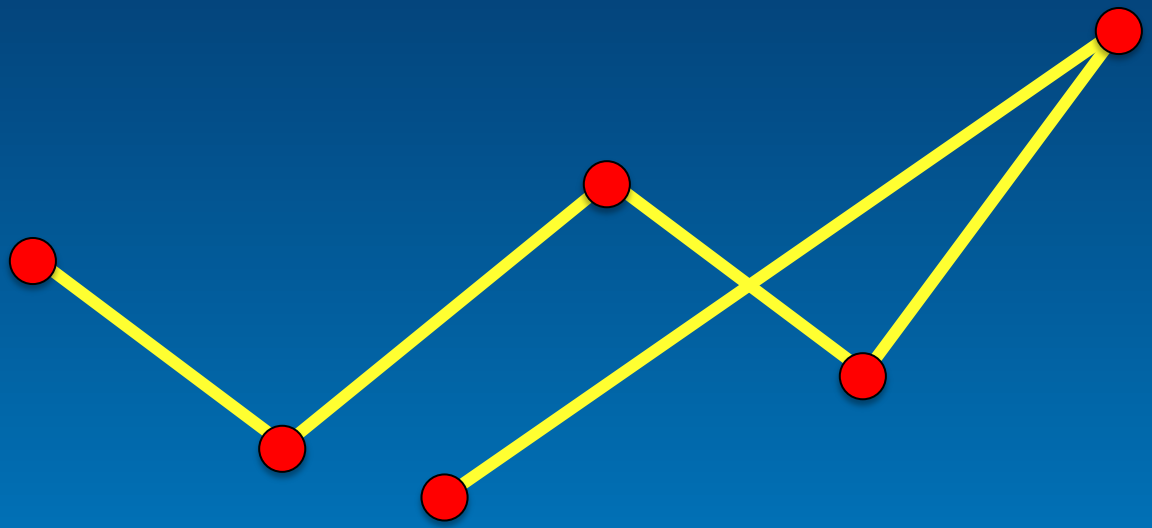


Polylines

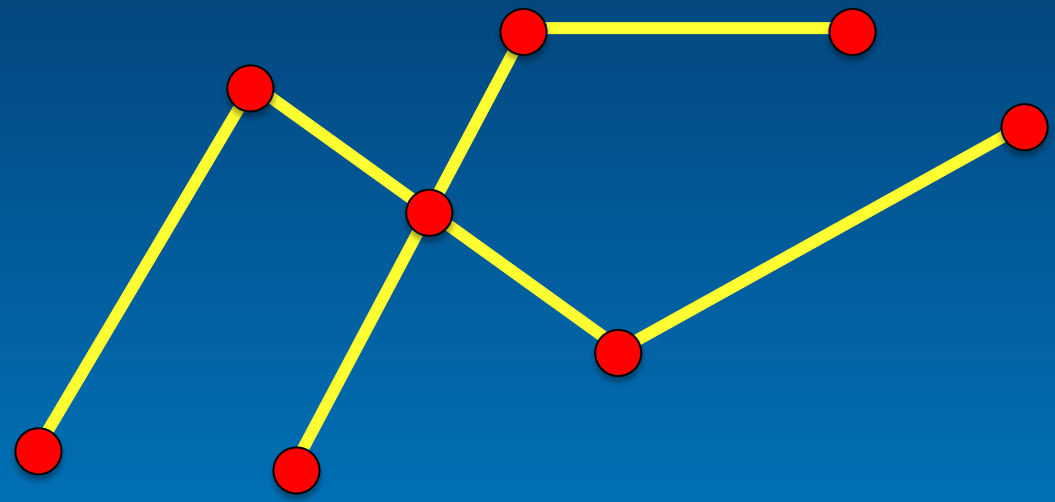
A collection of paths



Polylines



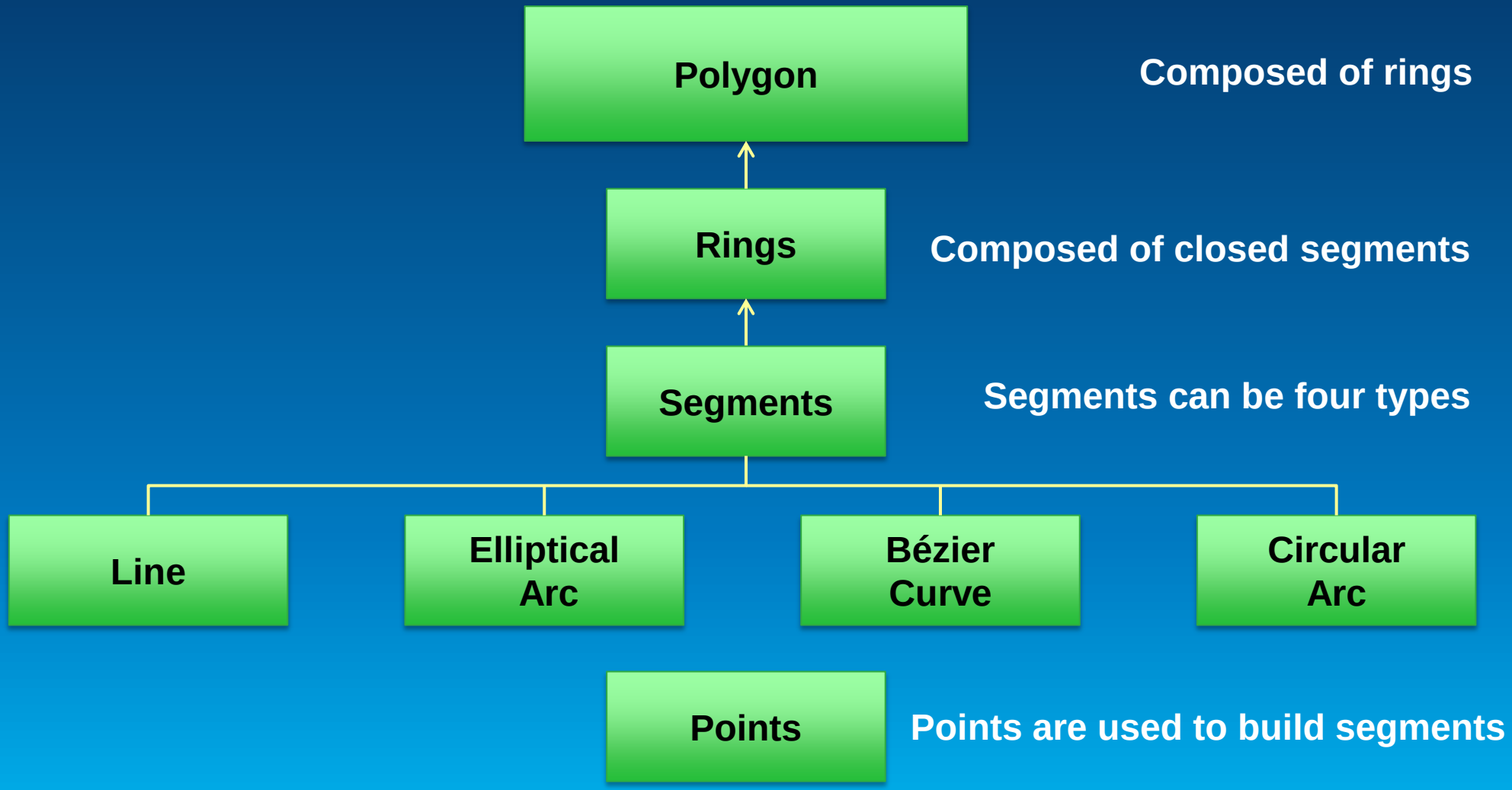
Single part



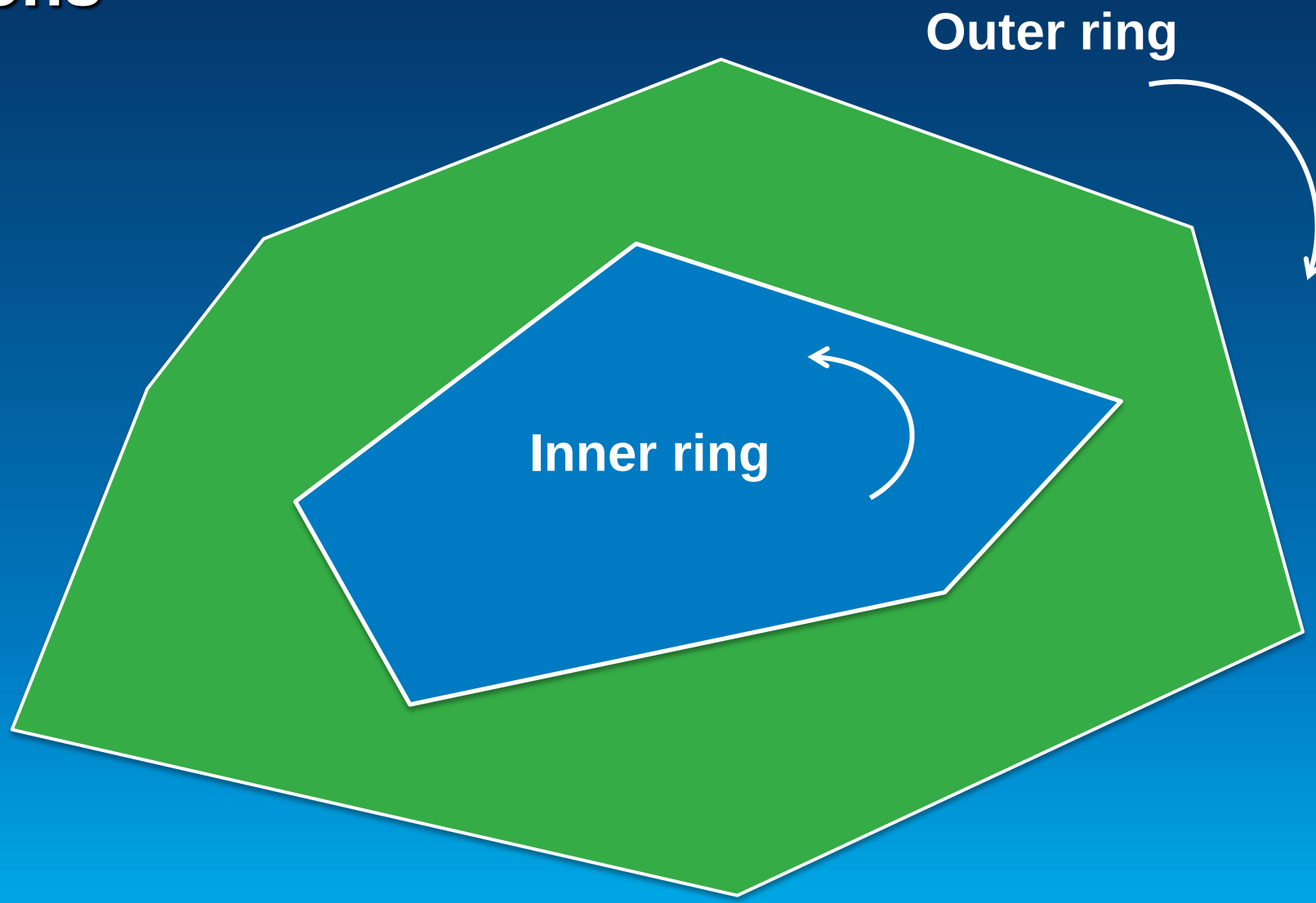
Multipart

Polygons

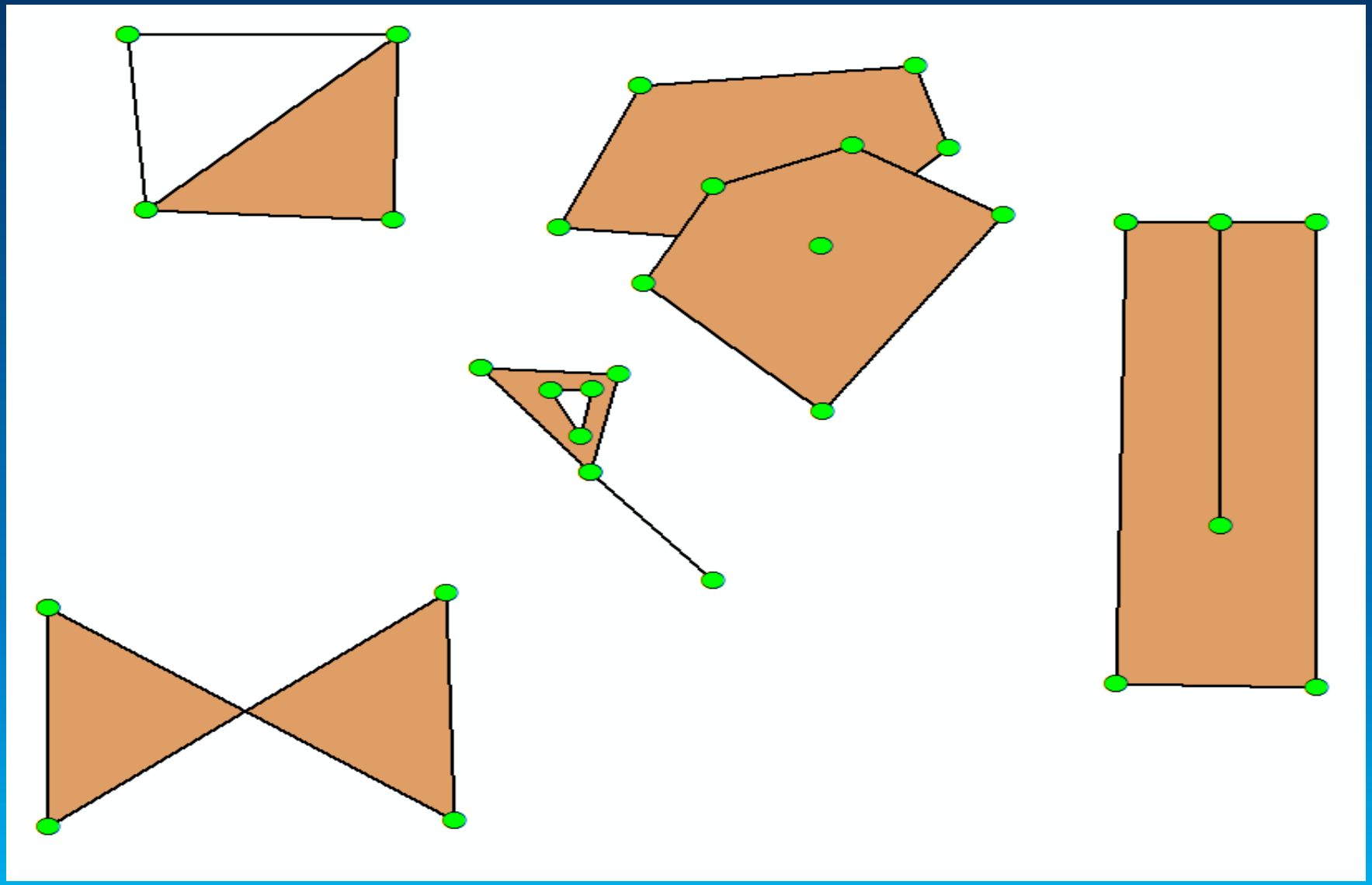
A collection of rings



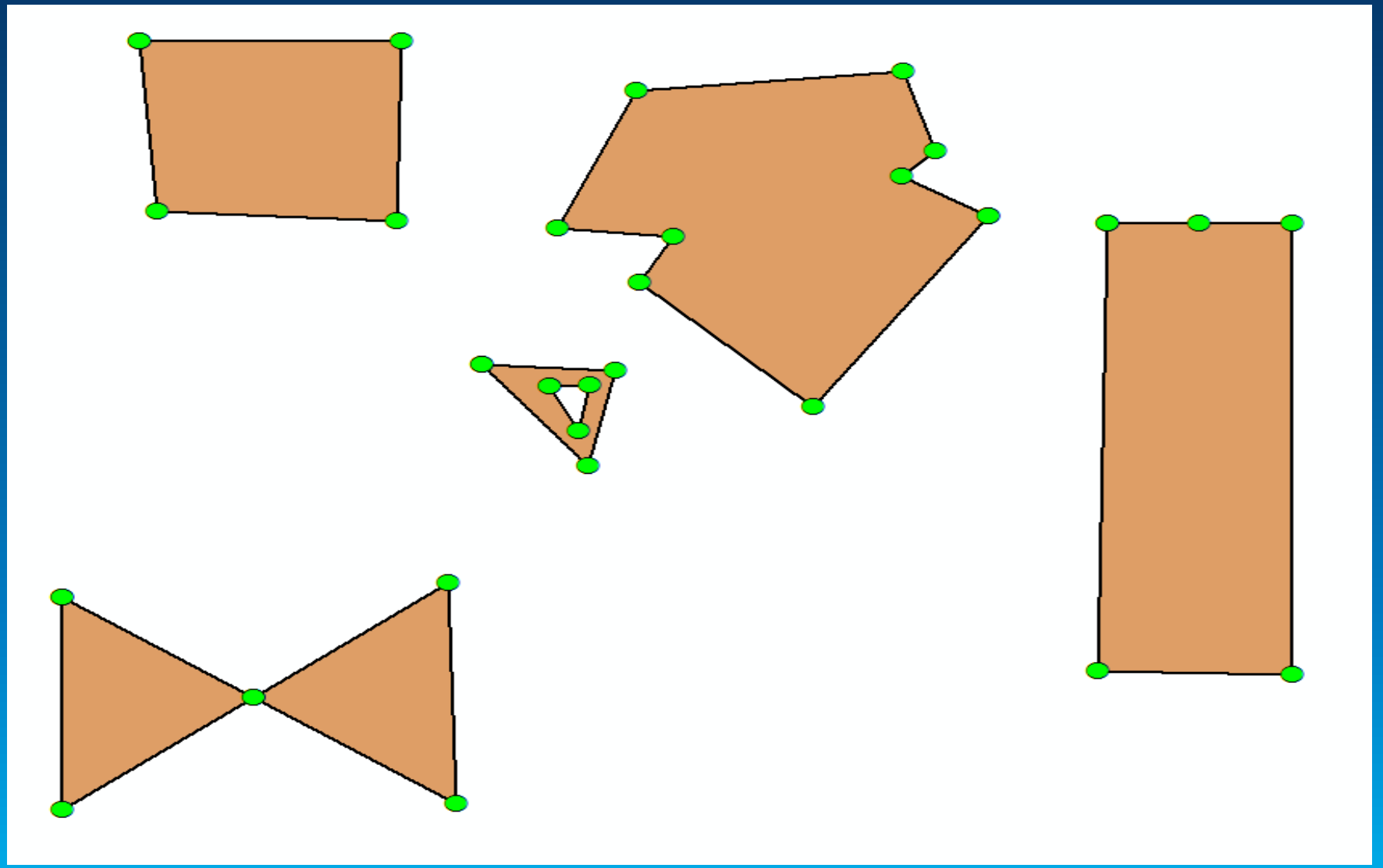
Polygons



Non-simple Polygons



Simple Polygons

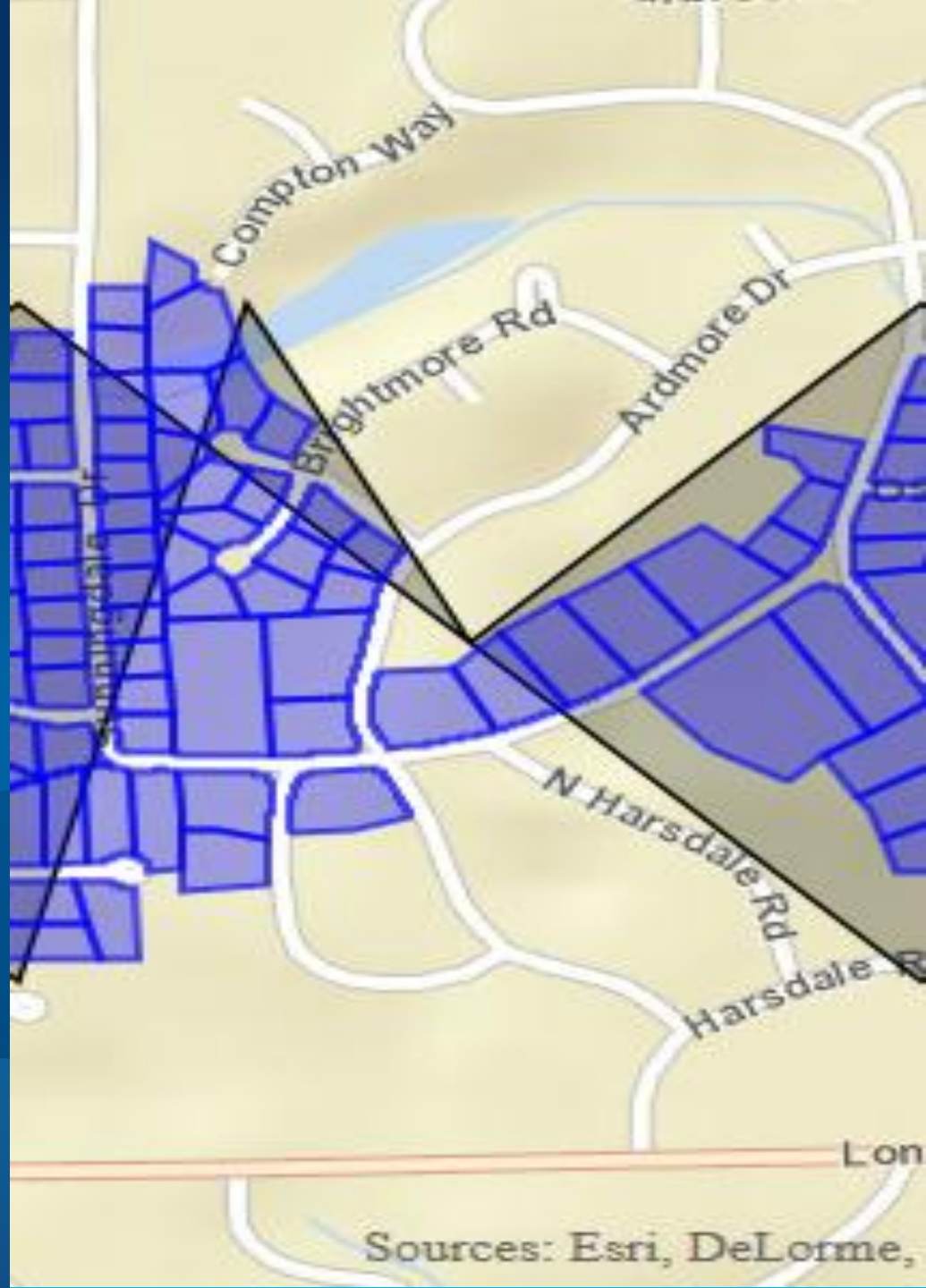


So what? Why do we care if geometries are simple?

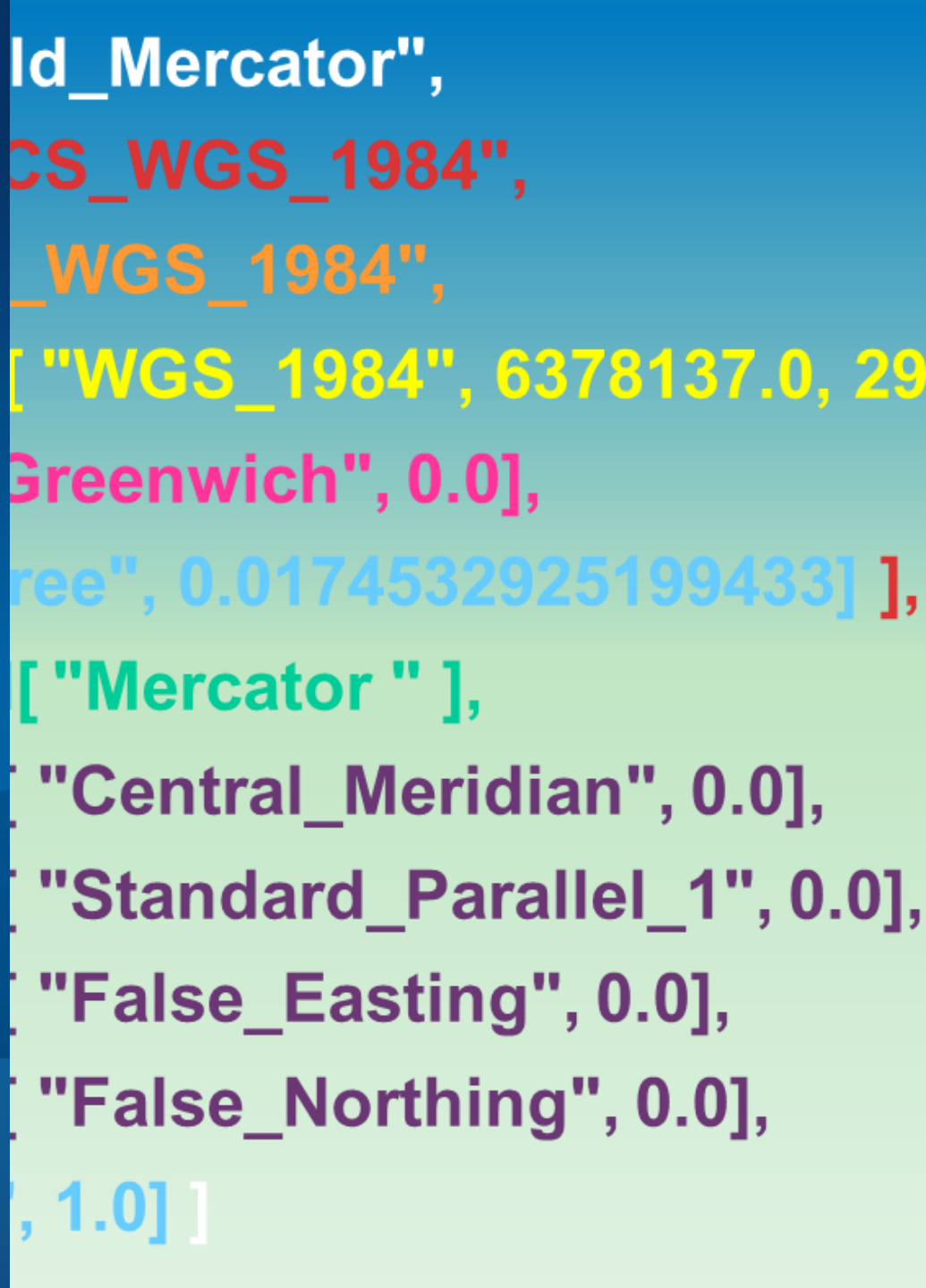
- Cannot rely on results from operations using non-simple geometries
- Get an error
- Get incorrect results

Why do we care if geometries are simple?

Demo



Spatial References

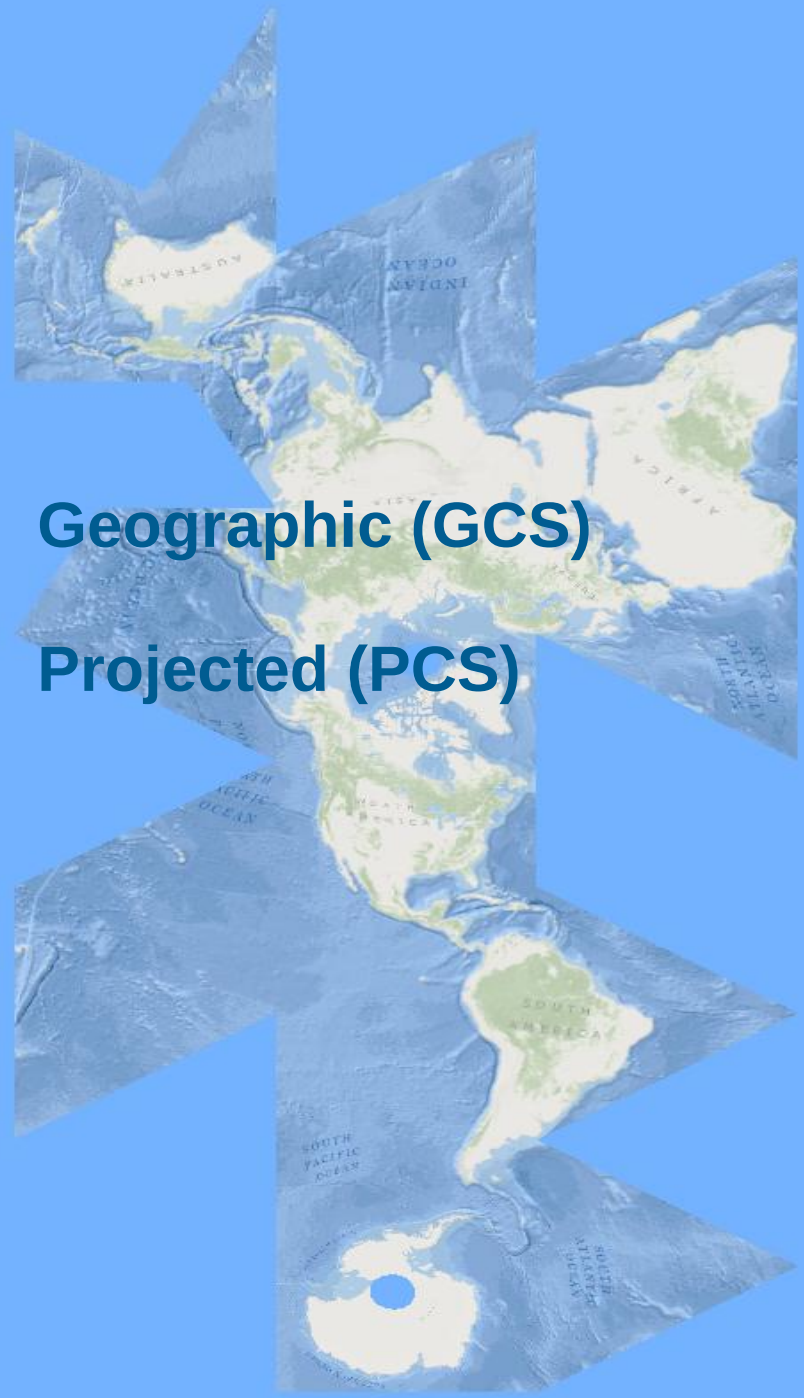


Spatial references

Key properties

- Coordinate system
  - Geographic
  - Projected
- XY Resolution
- XY Tolerance

Coordinate systems



Geographic (GCS)

Projected (PCS)

What is a coordinate system?

- An agreed upon way to describe locations

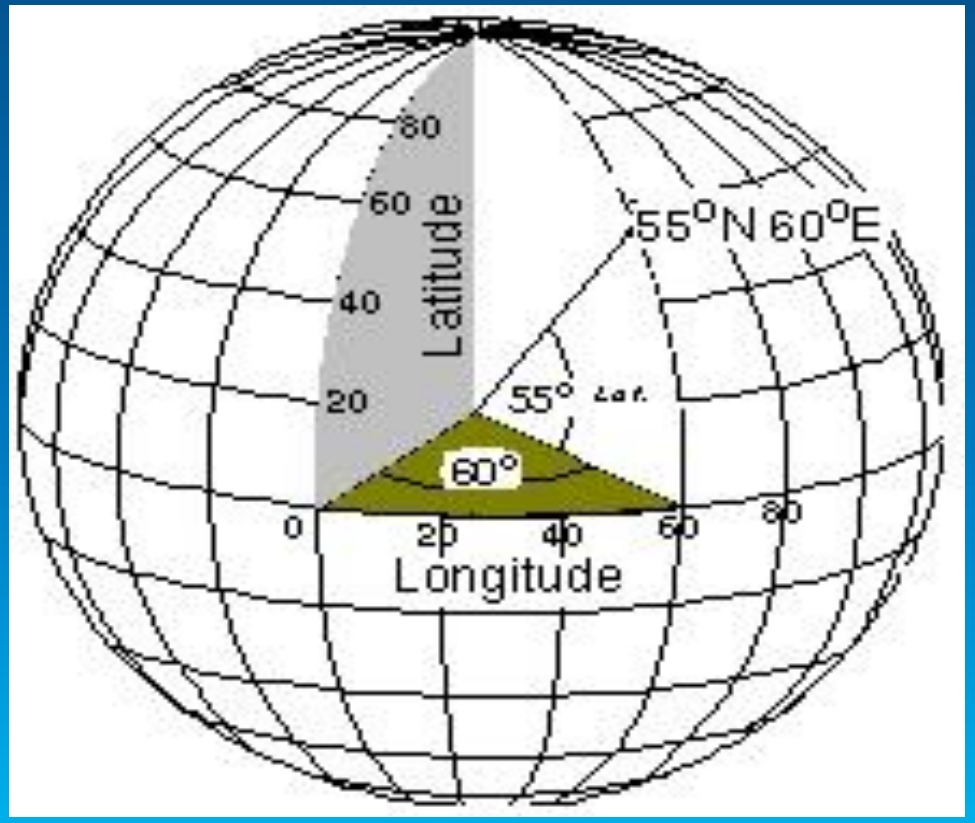
- Represents locations
  - Geographic features
  - Imagery
  - Observations such as GPS locations

- Common geographic framework

  Used to integrate geographic locations from different datasets

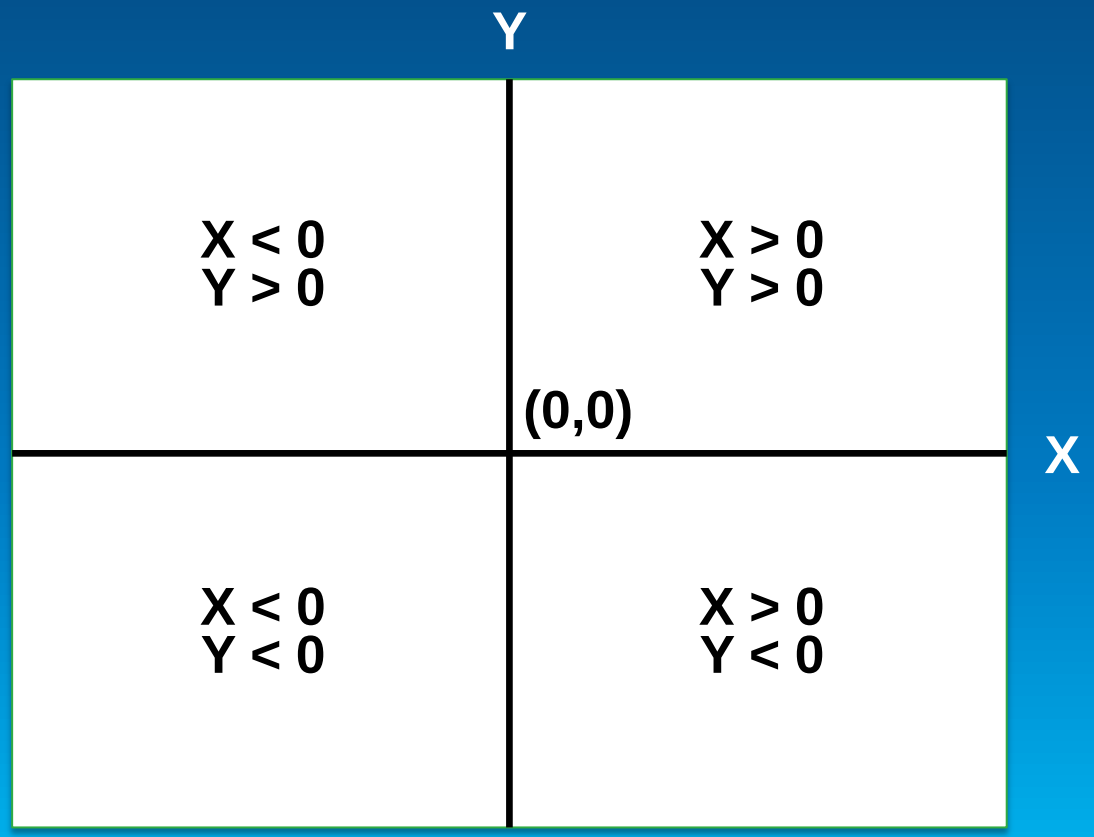
Geographic Coordinate System (GCS)

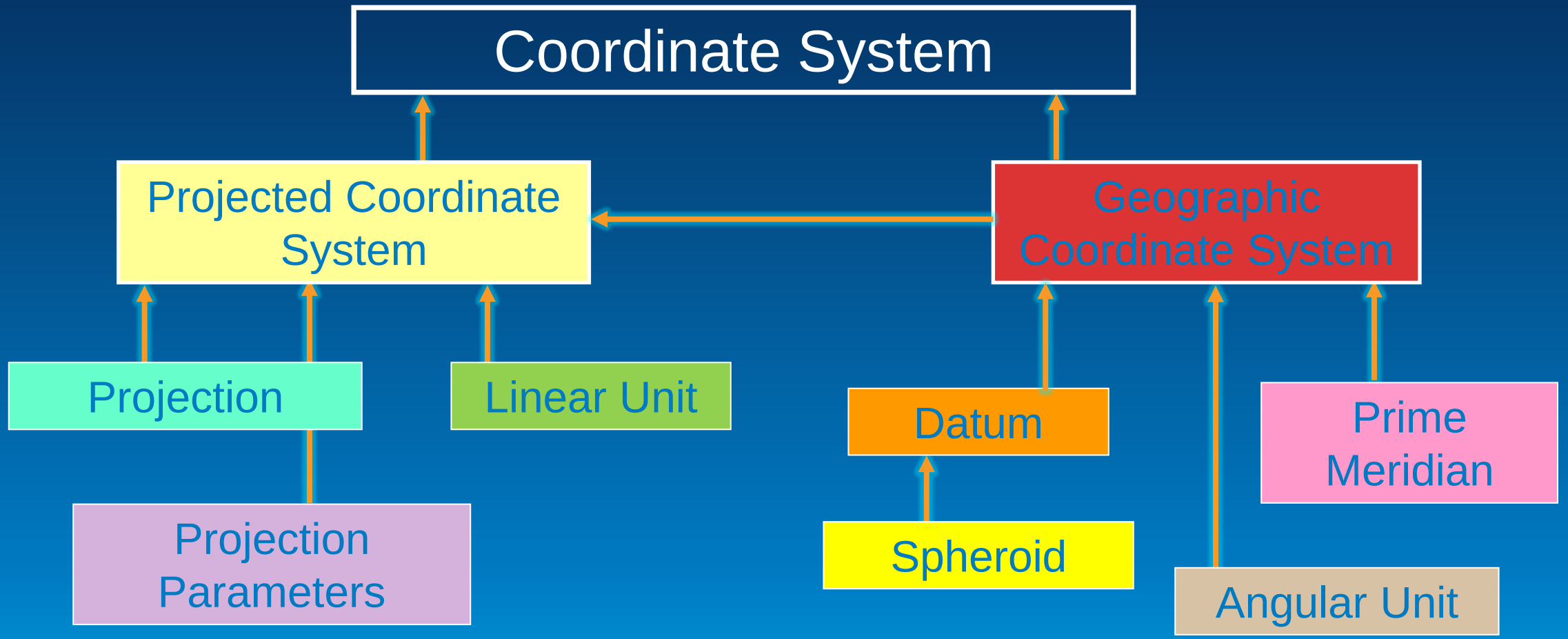
- Global – 3D spherical surface
- Point referenced by longitude and latitude values



Projected Coordinate System (PCS)

- Flat – 2D surface based on a GCS
- Point referenced by x, y coordinates on a grid

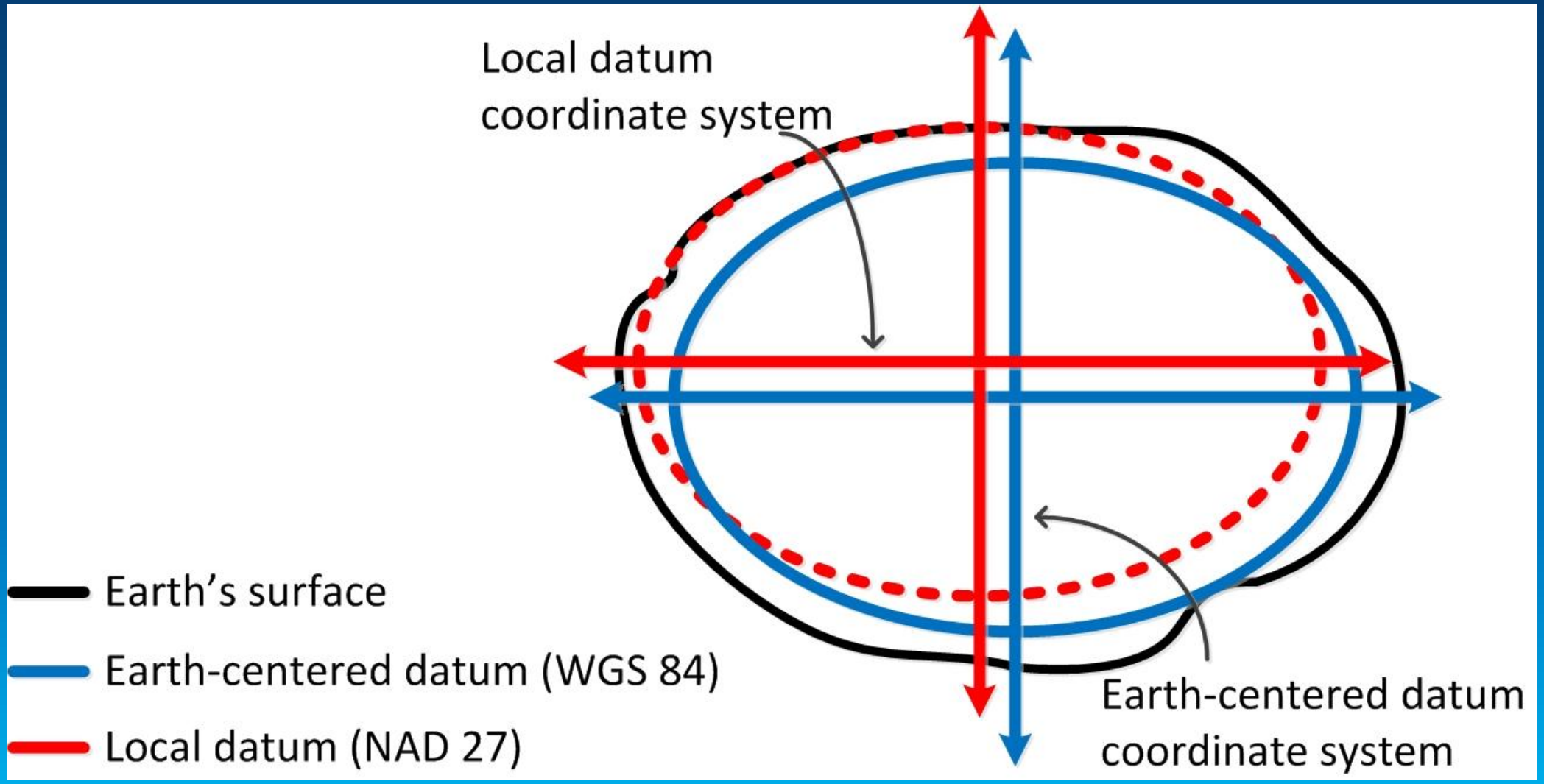



Coordinate System
Projected Coordinate System
Geographic Coordinate System
Projection
Linear Unit
Datum
Prime Meridian
Projection Parameters
Spheroid
Angular Unit

Geographic Coordinate System
Well-Known Text (WKT)

```
GEOGCS[ "GCS_WGS_1984",
    DATUM[ "D_WGS_1984",
        SPHEROID[ "WGS_1984", 6378137.0, 298.257223563] ],
    PRIMEM[ "Greenwich", 0.0],
    UNIT[ "Degree", 0.0174532925199433] ]
```

What is a datum?



Projected Coordinate System Well-Known Text (WKT)

```
PROJCS[ “World_Mercator",
  GEOGCS[ "GCS_WGS_1984",
    DATUM[ "D_WGS_1984",
        SPHEROID[ "WGS_1984", 6378137.0, 298.257223563] ],
    PRIMEM[ "Greenwich", 0.0],
    UNIT[ "Degree", 0.0174532925199433] ],
  PROJECTION[ "Mercator " ],
  PARAMETER[ "Central_Meridian", 0.0],
  PARAMETER[ "Standard_Parallel_1", 0.0],
  PARAMETER[ "False_Easting", 0.0],
  PARAMETER[ "False_Northing", 0.0],
  UNIT[ “Meter", 1.0] ]
```

Well-Known ID (WKID)

- Every predefined coordinate system has a WKID
  - For example, GCS_WGS_1984, WKID = 4326

- WKID < 32767 is EPSG assigned
  - EPSG Geodetic Parameter Dataset, http://www.epsg-registry.org/

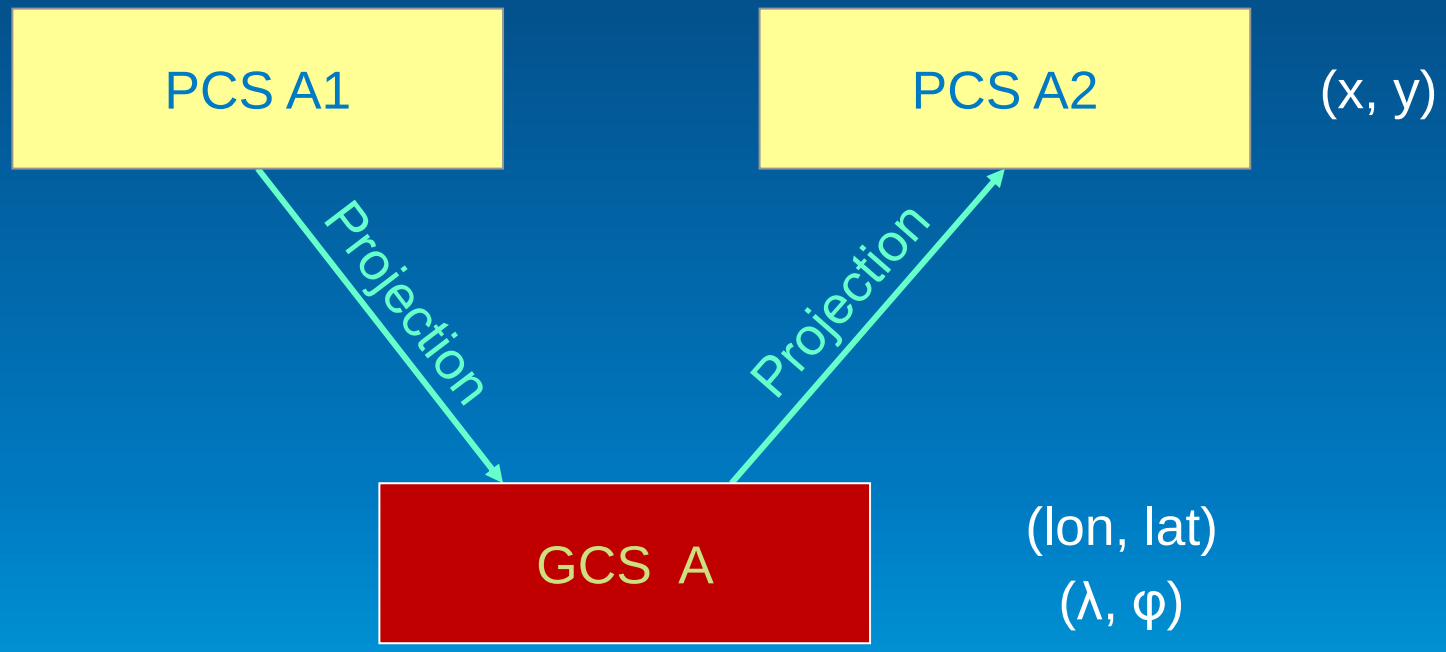
- WKID > 32767 is Esri assigned
  - Esri WKID may change
  - Esri → EPSG
  - Old WKID will still work
  - Example, Web Mercator 102100 → 3857

All projections have some distortion

Web Mercator Projection

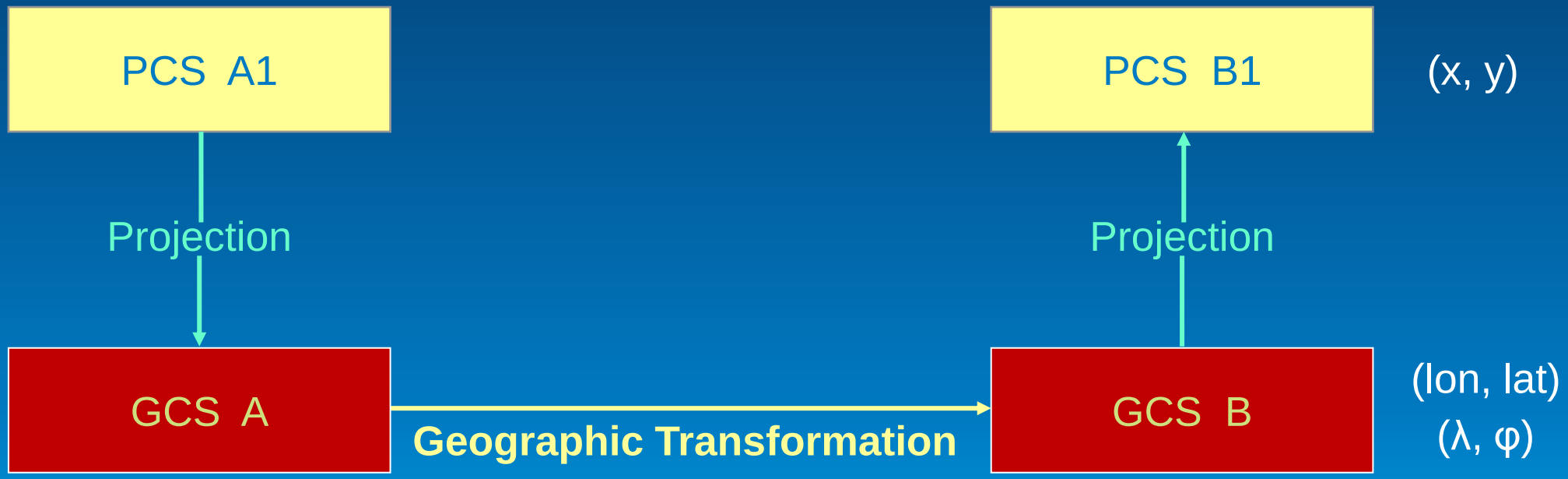
What is happening when we project data?

Case 1: Both PCSs contain the same GCS



What is happening when we project data?

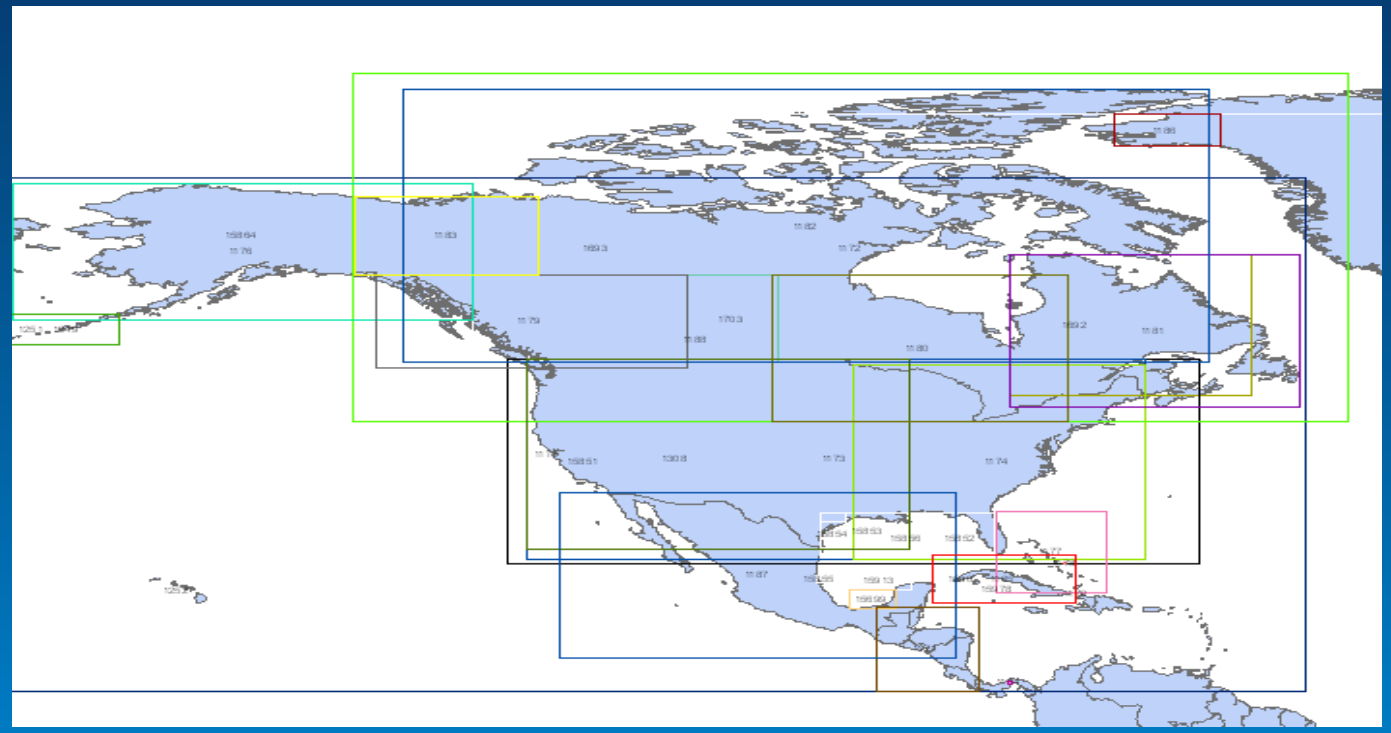
Case 2: Each PCS contains a different GCS



Geographic Transformations (GT)

- Convert from one GCS to another GCS
- Suitable for a particular area
- Defined in a particular direction
  - For example, NAD27 to WGS84
  - All are reversible
- May be more than one applicable GT

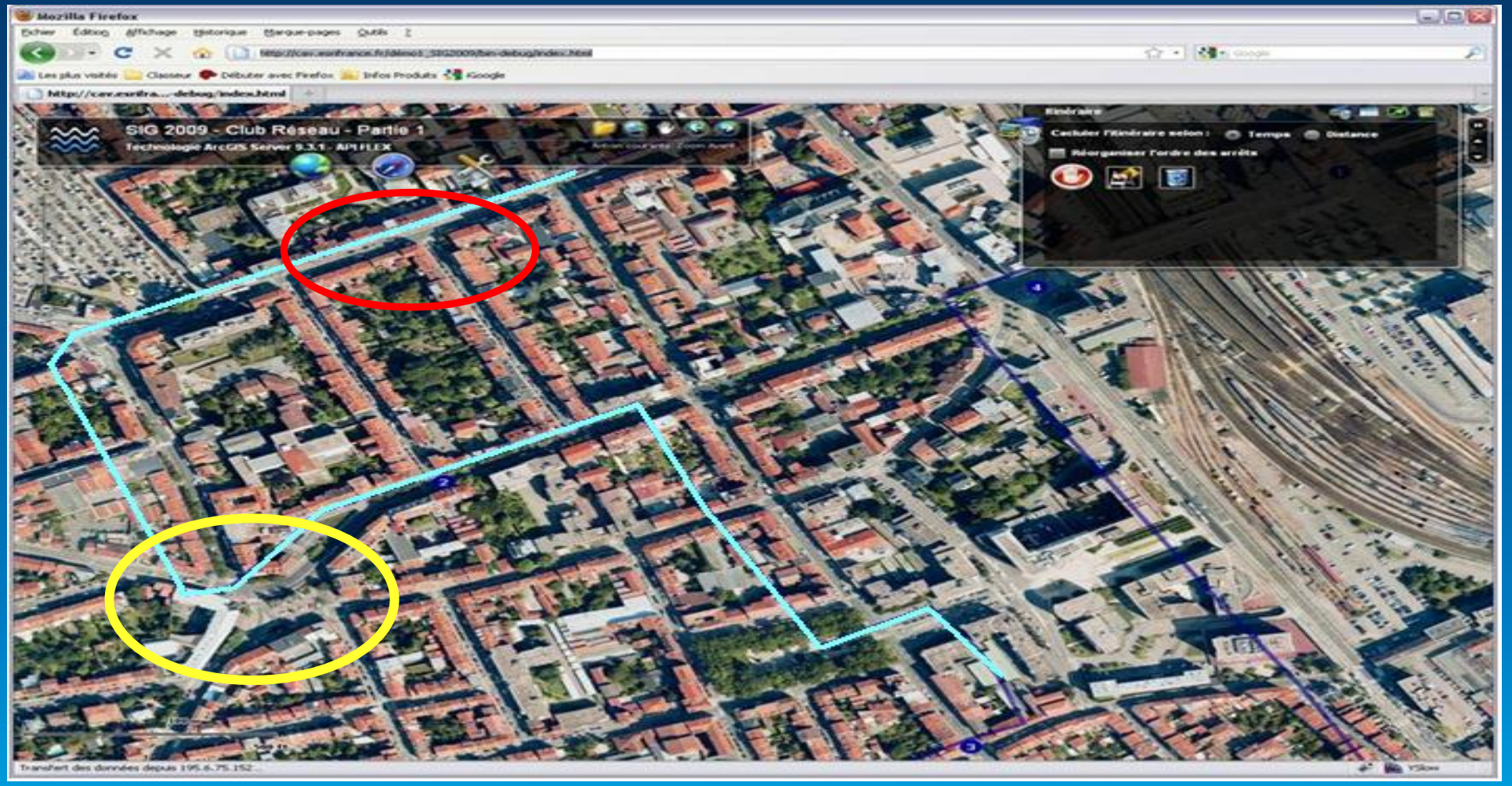
There are 38 transformations between GCS_North_American_1927 and GCS_WGS_1984



Which is best?

Depends on the region covered by your data

Why do we need to transform our data?

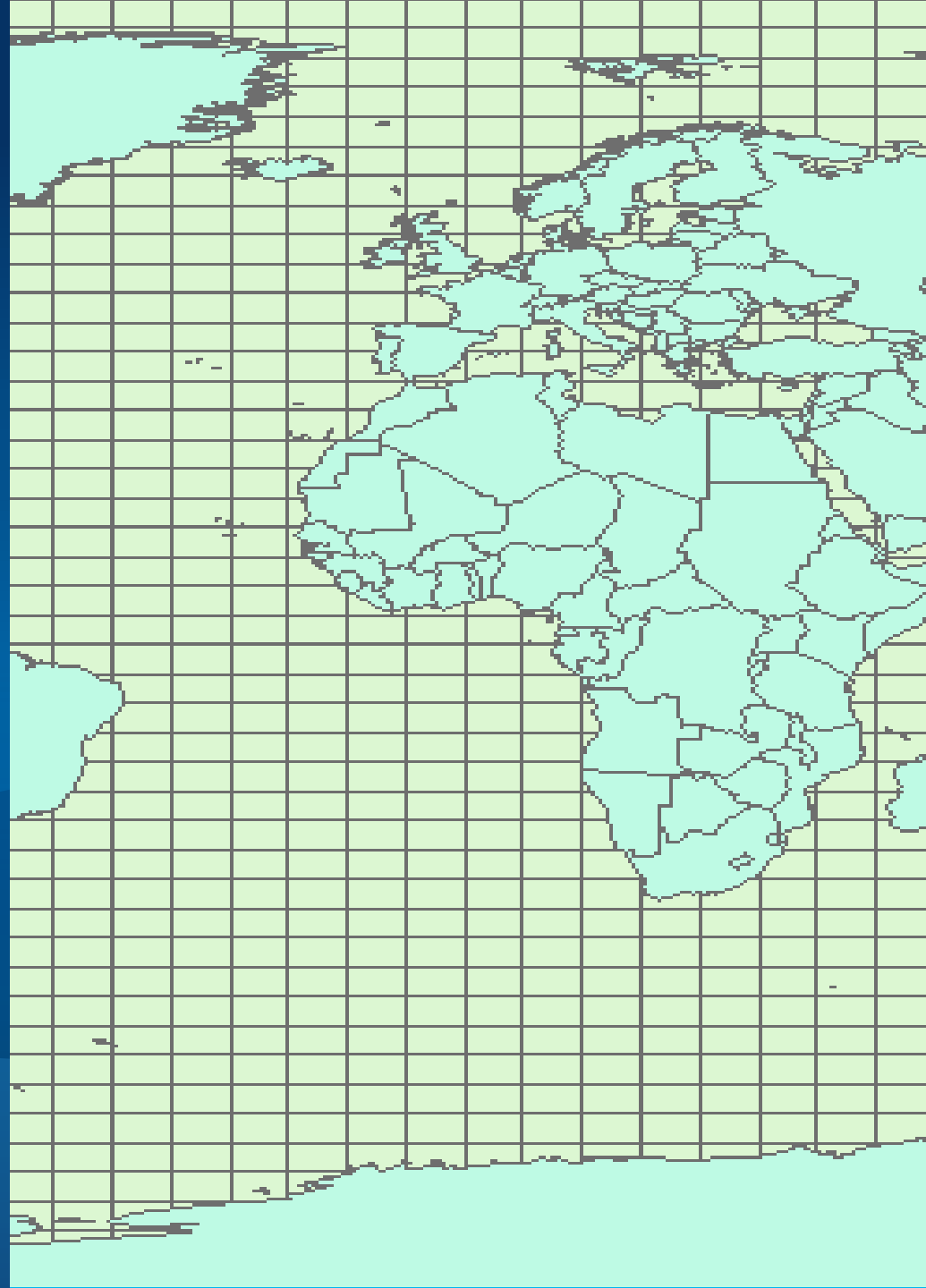


European Datum 1950 vs. World Geodetic System 1984

Projection between different GCSs

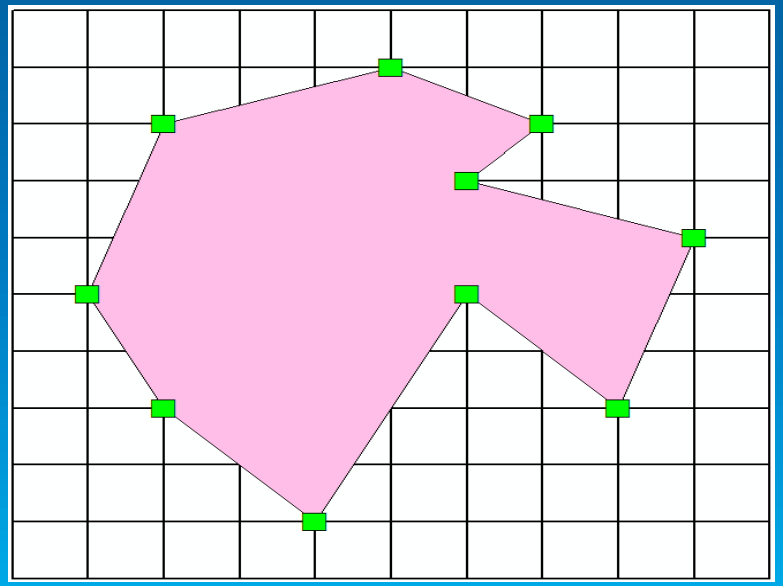
Demo

Resolution and Tolerance



XY Resolution

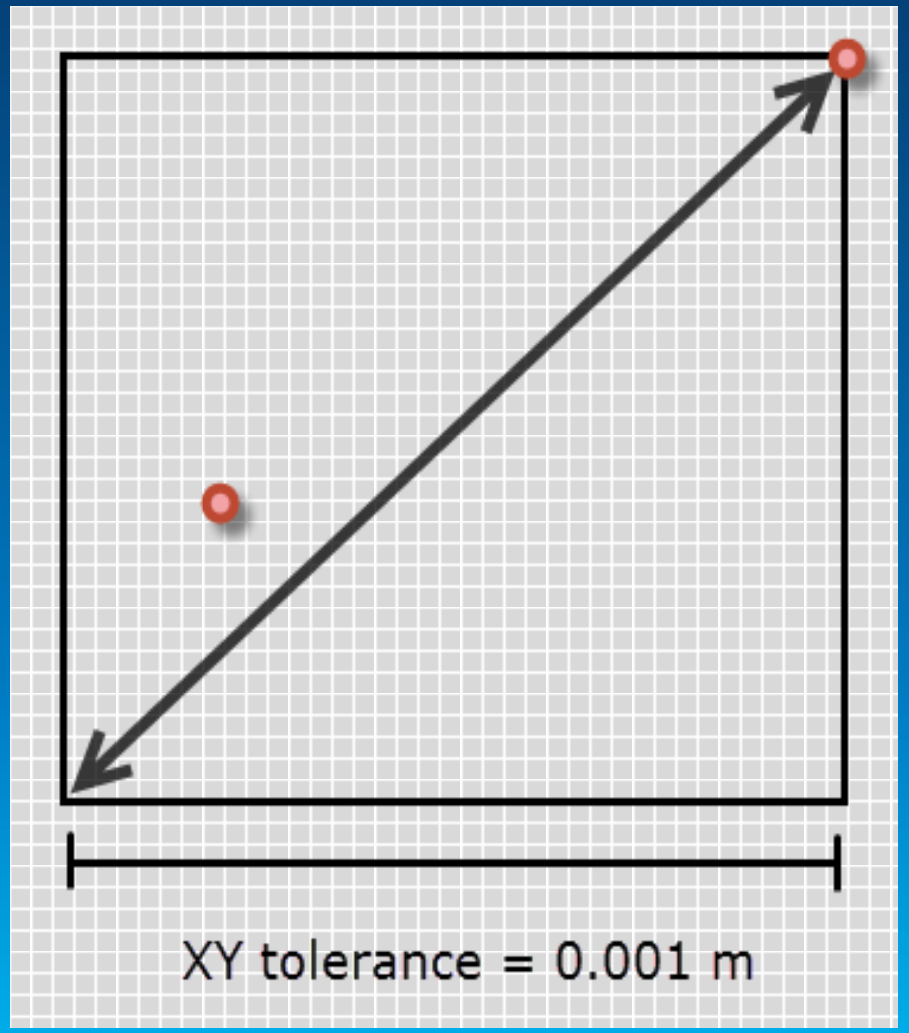
- Numeric precision used to store x, y coordinate values
- All coordinates lie on coordinate grid
- Default value is 0.0001 meters or equivalent
  - x_1 = 5.1234, x_2 = 5.1235 stored as unique coordinate values
  - x_1 = 5.12344, x_2 = 5.12345 both stored as 5.1234
  - Each square in grid is 0.0001 x 0.0001



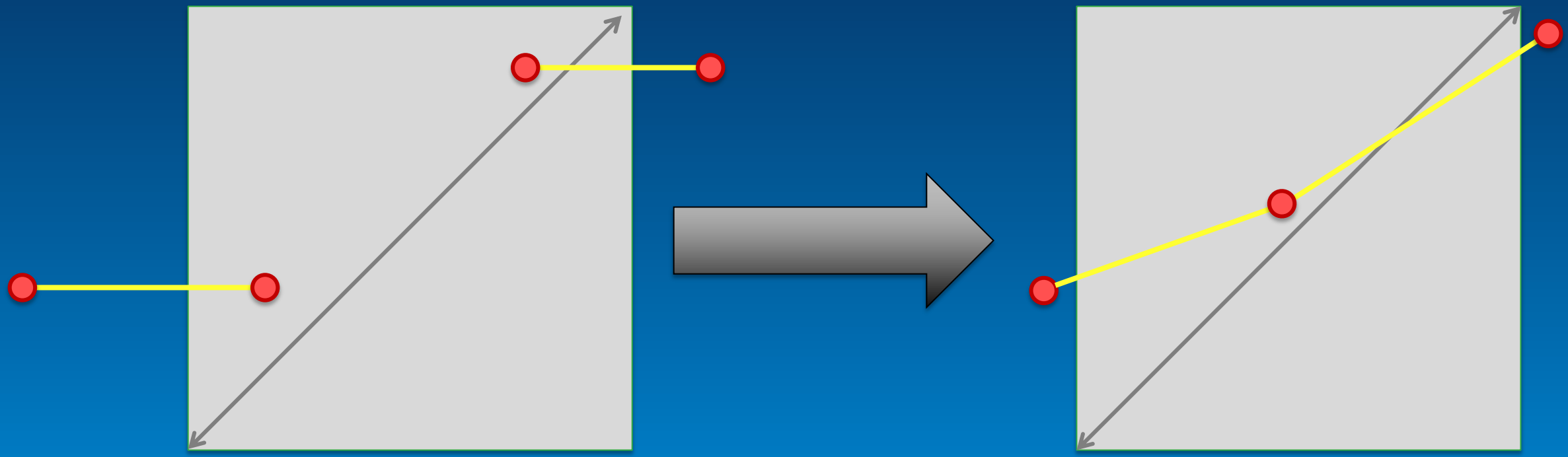
XY Tolerance

Minimum distance between coordinates when processing features

- Simple geometry validation
- Topological operations such as Buffer
- Relational operations
- Editing operations

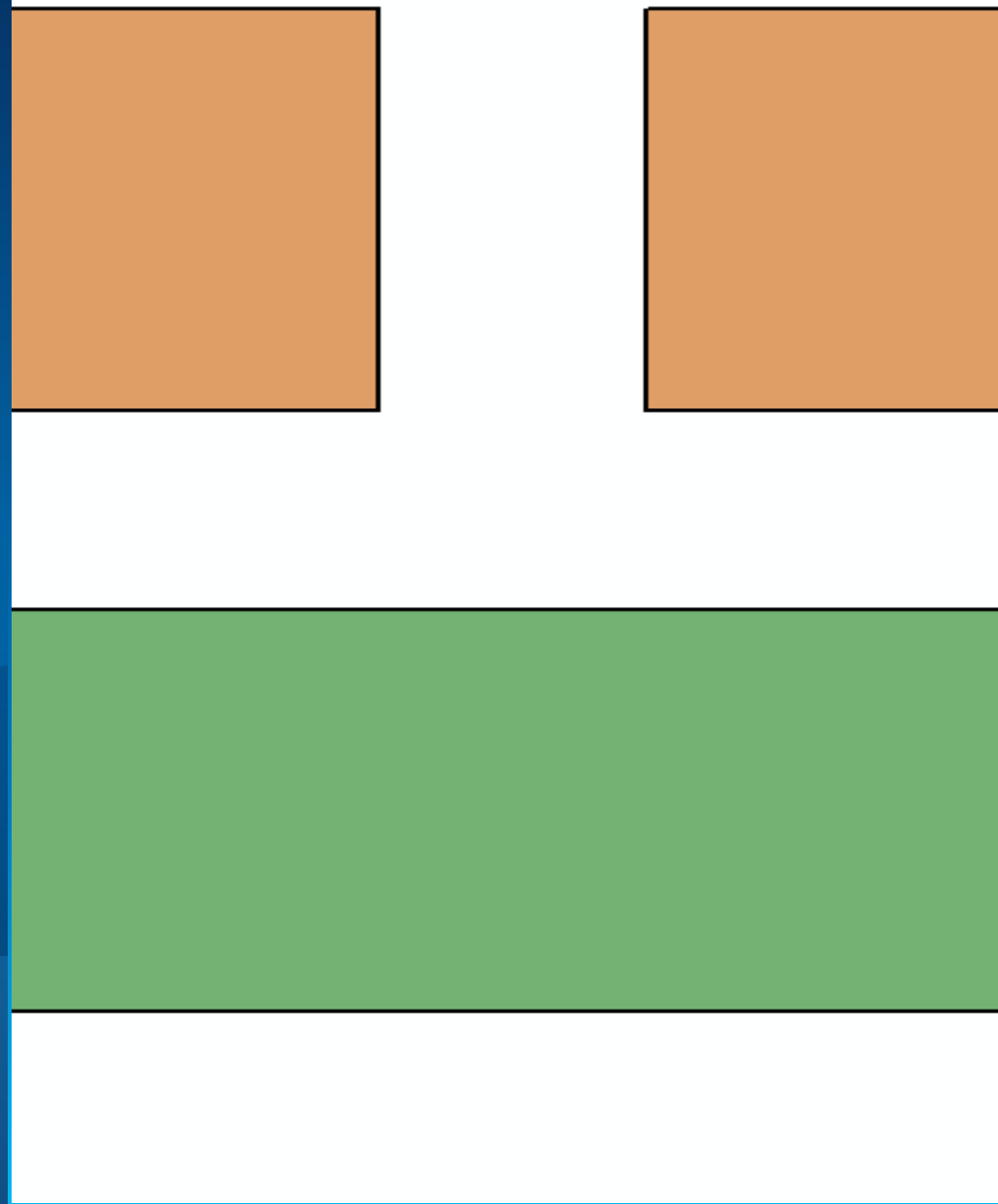


XY Tolerance



Merge polygons

Demo



Resolution vs. Tolerance

- Resolution: refers to number of decimal places used to store x, y coordinate values
- Tolerance: minimum separation between features used by some operations
  - Should never be less than 10 times resolution

- Default resolution = 0.0001 meter or equivalent
- Default tolerance = 0.001 meter or equivalent

- **Highly recommended to use default values!**

What do spatial references have to do with geometries?

- Geometry is a collection of points
- Spatial reference determines
  - where the coordinates are placed
  - how the coordinates interact with each other

How does a spatial reference affect a geometry?

- We need to know where to put the geometry on the map
- A geometry that is simple in one spatial reference may not be so in another spatial reference

  Remember, garbage in, garbage out
- An operation on features may give different results depending on the spatial reference

Where on the map do I put the geometry?

Demo

How does a spatial reference affect a geometry?

- We need to know where to put the geometry on the map
- A geometry that is simple in one spatial reference may not be so in another spatial reference

  Remember, garbage in, garbage out
- An operation on features may give different results depending on the spatial reference

What is simple here may not be simple there

Demo

How does a spatial reference affect a geometry?

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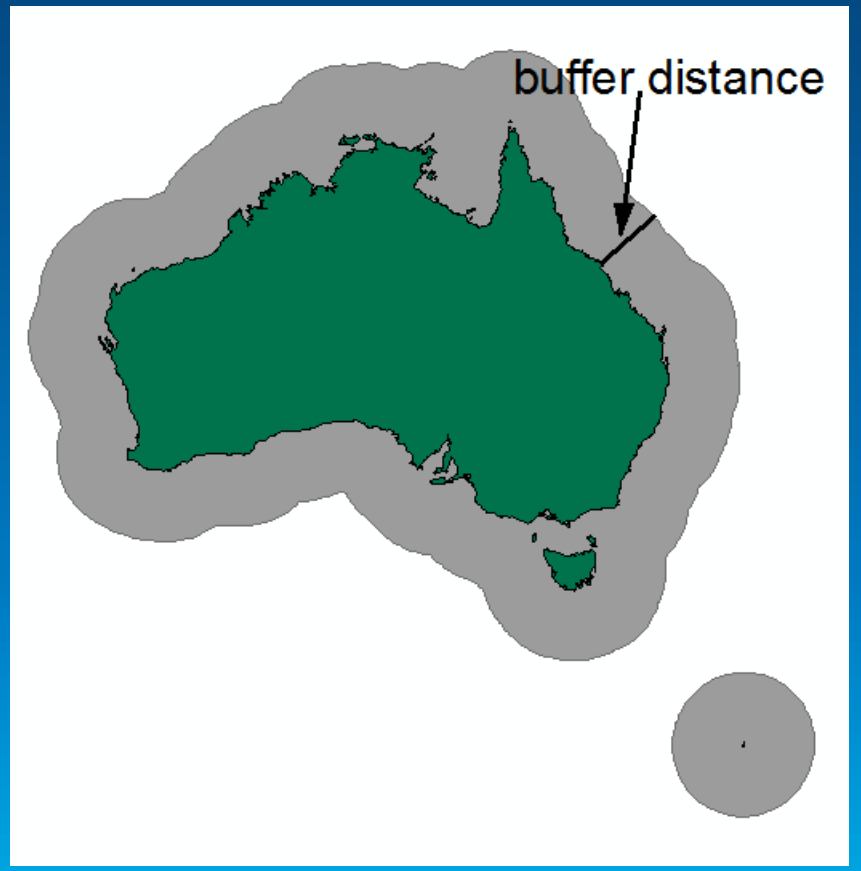
  Remember, garbage in, garbage out
- **An operation on features may give different results depending on the spatial reference**

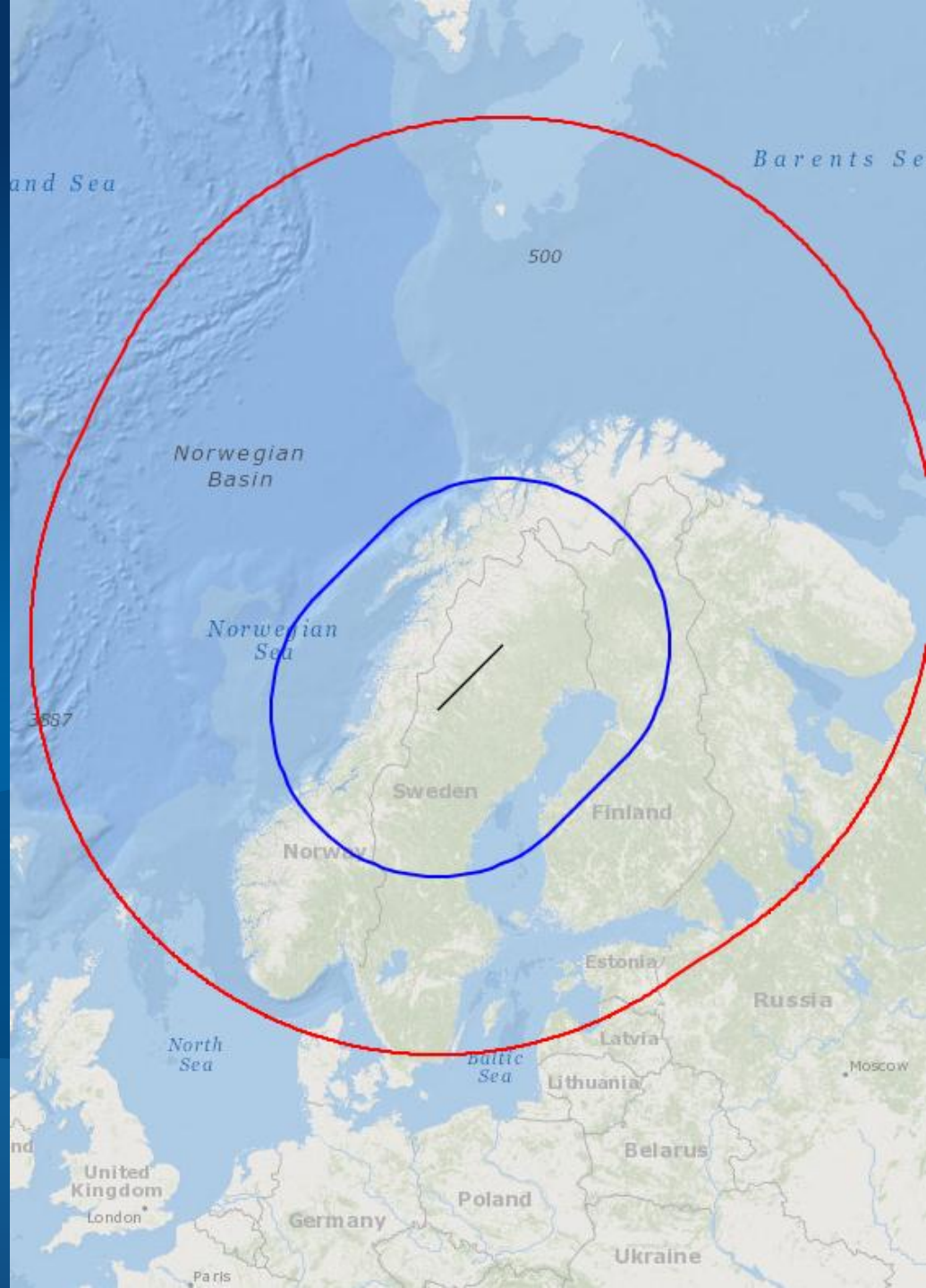
An operation on features may give different results depending on the spatial reference

For example, Buffer operation



Buffer and Spatial Reference

Demo



Resources

- http://resources.arcgis.com/en/help
  - *Desktop → Guide Books → Map projections*
  - *Developer Help*
    - *List of ArcGIS APIs*

- *Lining Up Data in ArcGIS*, *Margaret Maher*

- **ESRI Technical paper: *Understanding Coordinate Management in the Geodatabase***

- **ESRI Technical paper: *Understanding Geometric Processing in ArcGIS***

Demos

All the demos are on GitHub at https://github.com/alocke/DevSummit2014

- ArcMap Demos
  - DevSummit2014.gdb
    - Projection between different GCSs (Project.mxd)
    - Merge polygons (MergePolygons.mxd)
    - What is simple here may not be simple there (OneSimplePolygon.mxd)
  - QM.gdb
    - Where on the map do I put the geometry? (QM.mxd)
- JavaScript Demos
  - Why do we care if geometries are simple? (SimplifyPolygon.html)
  - Buffer and Spatial Reference (GeodesicBufferWebMercator.html and GeodesicBufferOther.html)
- Python Toolbox to convert JSON to GDB (MyPythonToolbox.pyt)

That’s all folks!

Don’t forget to fill out the survey

Understanding and Using Geometry, Projections and Spatial Reference Systems in ArcGIS

Understanding our world.