The National Spatial Reference System: The Common Foundation of Surveying and GIS

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Great Lakes Regional Geodetic Advisor
NOAA/National Geodetic Survey
2022 IMAGIN Annual Conference

My Background

- B.S. Surveying Engineering at Michigan Tech
- Ph.D. in Geodetic Science at The Ohio State University

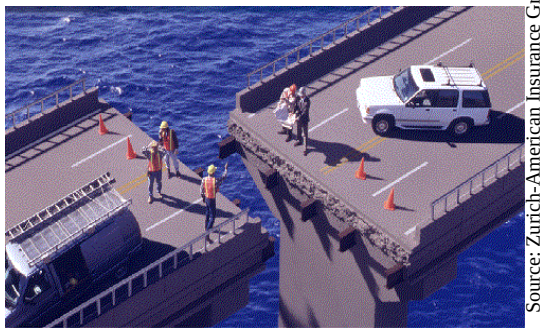
- NGS Headquarters (Geosciences Research Division) 2016-20
- Now the Great Lakes Regional Geodetic Advisor
- Professional Surveyor

Regional Geodetic Advisor Program

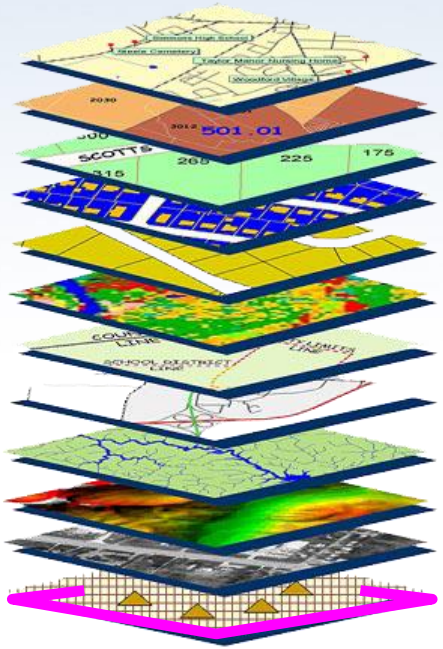
Accurate positioning begins with *accurate* coordinates

geodetic control (the NSRS) is the foundation for all geospatial products.

without Geodetic Control as a "base map" layer, GIS applications will not work properly



Source: Zurich-American Insurance Group



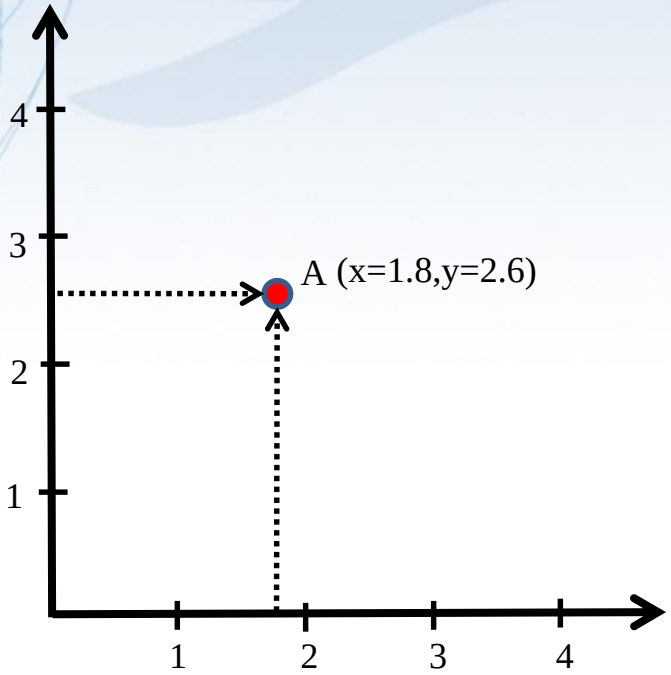
Find the coordinates of point A

Somewhere on Earth…

You are presented with this problem…

Without any other information, the problem is unsolvable.

Find the coordinates of point A

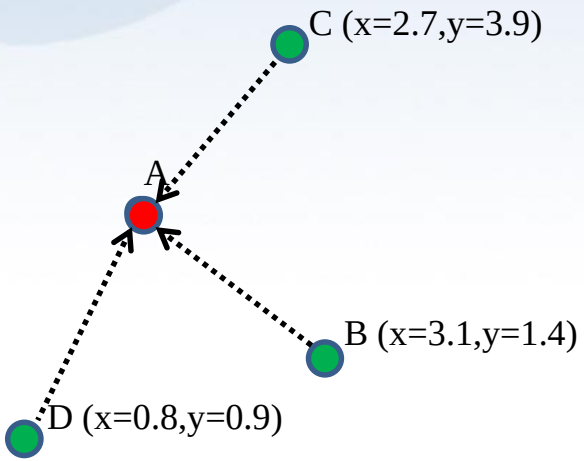


Wouldn't it be fantastic if someone just provided you with a coordinate system?

Unfortunately, the Earth doesn't come with lines of latitude and longitude just drawn all over it…

"The Earth is not a globe"

Find the coordinates of point A

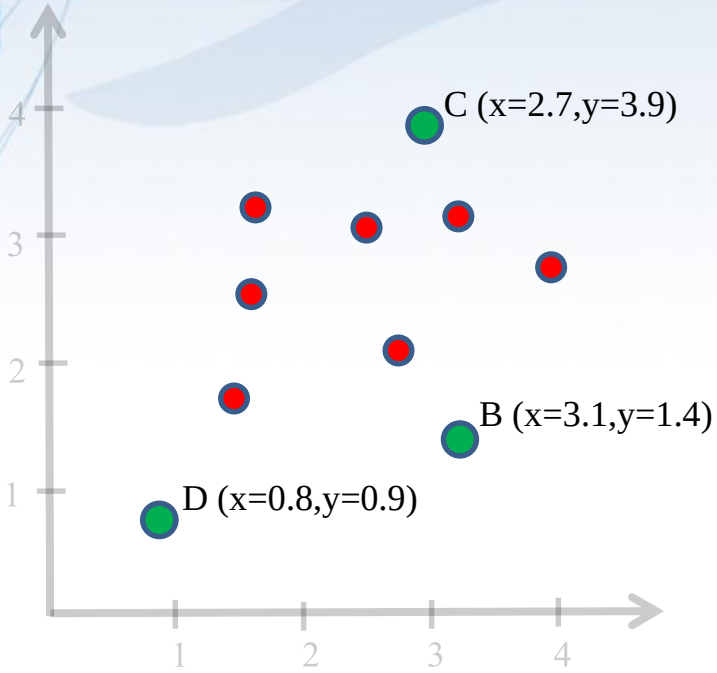


But what if someone gave you enough other points with pre-determined coordinates?

With a little measuring and trigonometry, you could certainly determine the coordinates of point A!

These "other points with pre-determined coordinates" are "**geodetic control**"

Find the coordinates of point A



Although the coordinate axes are not visible, their location and scale are *implied* by the given coordinates of the points B, C, and D.

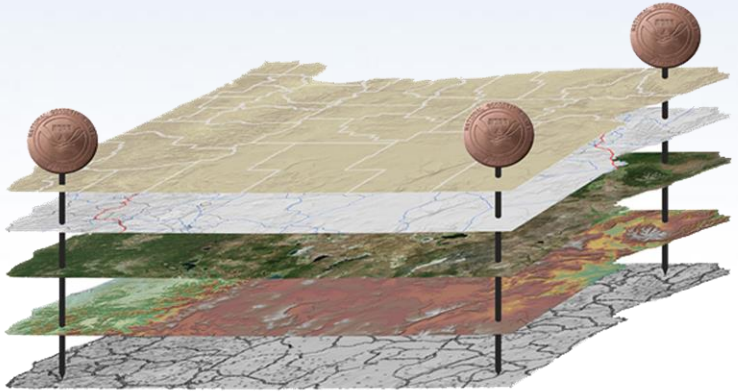
It is often the job of surveyors, mappers and other geospatial professionals to determine the coordinates of many points on Earth.

It is the job of NGS to provide the geodetic control to the nation to make those jobs possible.

The National Spatial Reference System (NSRS)

NGS defines, maintains and provides access to the NSRS to meet our Nation's economic, social & environmental needs

Latitude • Longitude • Elevation
• Gravity • Shoreline Position
+ changes over time



- North American Datum of 1983 **(NAD 83)**
- North American Vertical Datum of 1988 **(NAVD 88)**

Today's NSRS

Passive Control

The NGS Data Sheet

See file dsdata.pdf for more information about the datasheet.

```
PROGRAM = datasheet95, VERSION = 8.12.5.12
Starting Datasheet Retrieval...
1       National Geodetic Survey,   Retrieval Date = JUNE 25, 2021
 AJ8317 ***********************************************************************
 AJ8317  SACS         -  This is a Secondary Airport Control Station.
 AJ8317  DESIGNATION -  SPI B
 AJ8317  PID          -  AJ8317
 AJ8317  STATE/COUNTY-  IL/SANGAMON
 AJ8317  COUNTRY      -  US
 AJ8317  USGS QUAD    -  SPRINGFIELD WEST (2018)
 AJ8317
 AJ8317                        *CURRENT SURVEY CONTROL
 AJ8317  ______________________________________________________________________
 AJ8317* NAD 83(2011) POSITION- 39 50 22.48941(N) 089 39 57.06655(W)   ADJUSTED
 AJ8317* NAD 83(2011) ELLIP HT-   144.479 (meters)        (06/27/12)   ADJUSTED
 AJ8317* NAD 83(2011) EPOCH    2010.00
 AJ8317* NAVD 88 ORTHO HEIGHT -   177.097 (meters)      581.03  (feet) ADJUSTED
 AJ8317  ______________________________________________________________________
 AJ8317  GEOID HEIGHT    -        -32.599 (meters)                     GEOID18
 AJ8317  NAD 83(2011) X  -     28,601.347 (meters)                     COMP
 AJ8317  NAD 83(2011) Y  - -4,904,165.278 (meters)                     COMP
 AJ8317  NAD 83(2011) Z  -  4,064,417.425 (meters)                     COMP
 AJ8317  LAPLACE CORR    -          0.92  (seconds)                    DEFLEC18
 AJ8317  DYNAMIC HEIGHT  -       177.000 (meters)      580.71  (feet) COMP
 AJ8317  MODELED GRAVITY -    980,078.4   (mgal)                       NAVD 88
 AJ8317
 AJ8317  VERT ORDER      -  SECOND    CLASS I
```

The National Spatial Reference System (NSRS)

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Latitude • Longitude • Elevation
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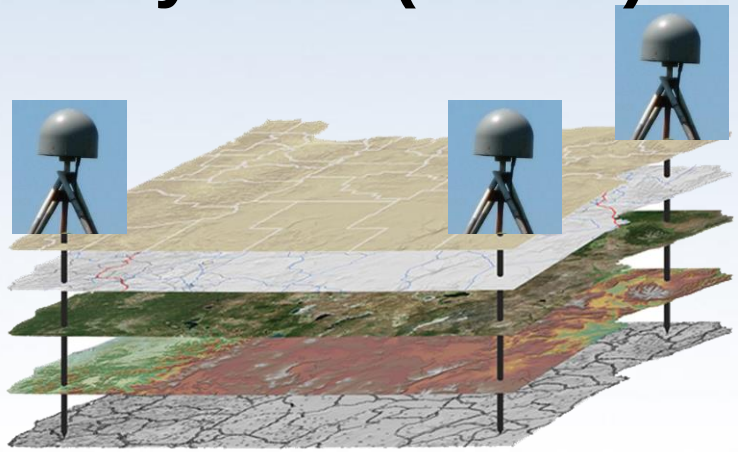
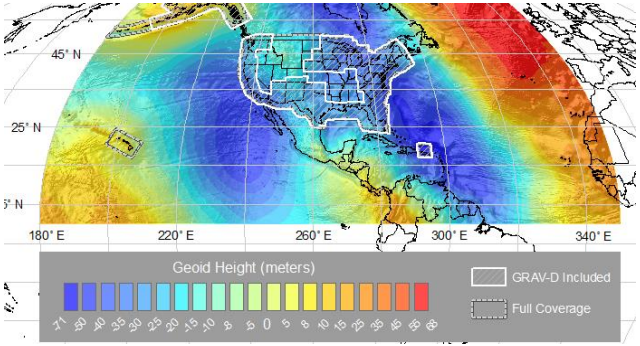


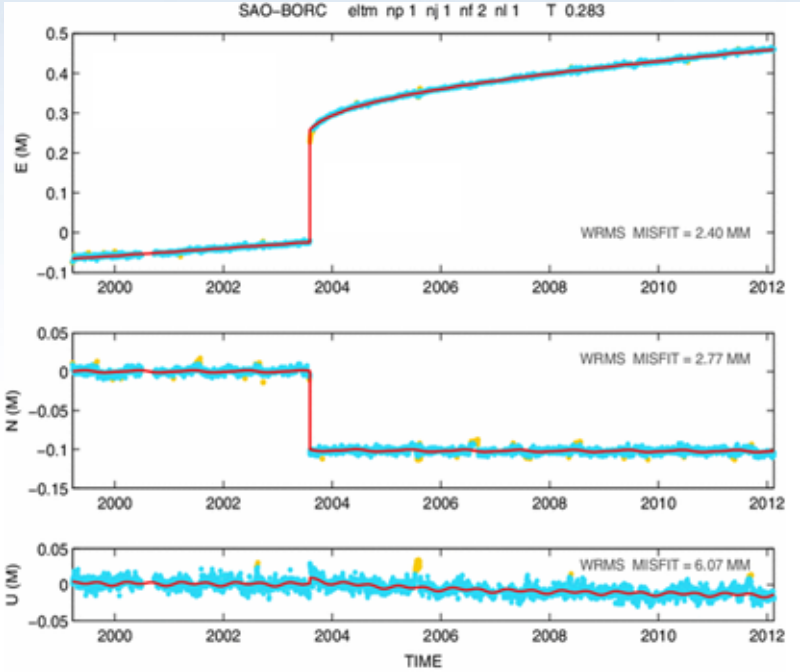
Tomorrow's NSRS



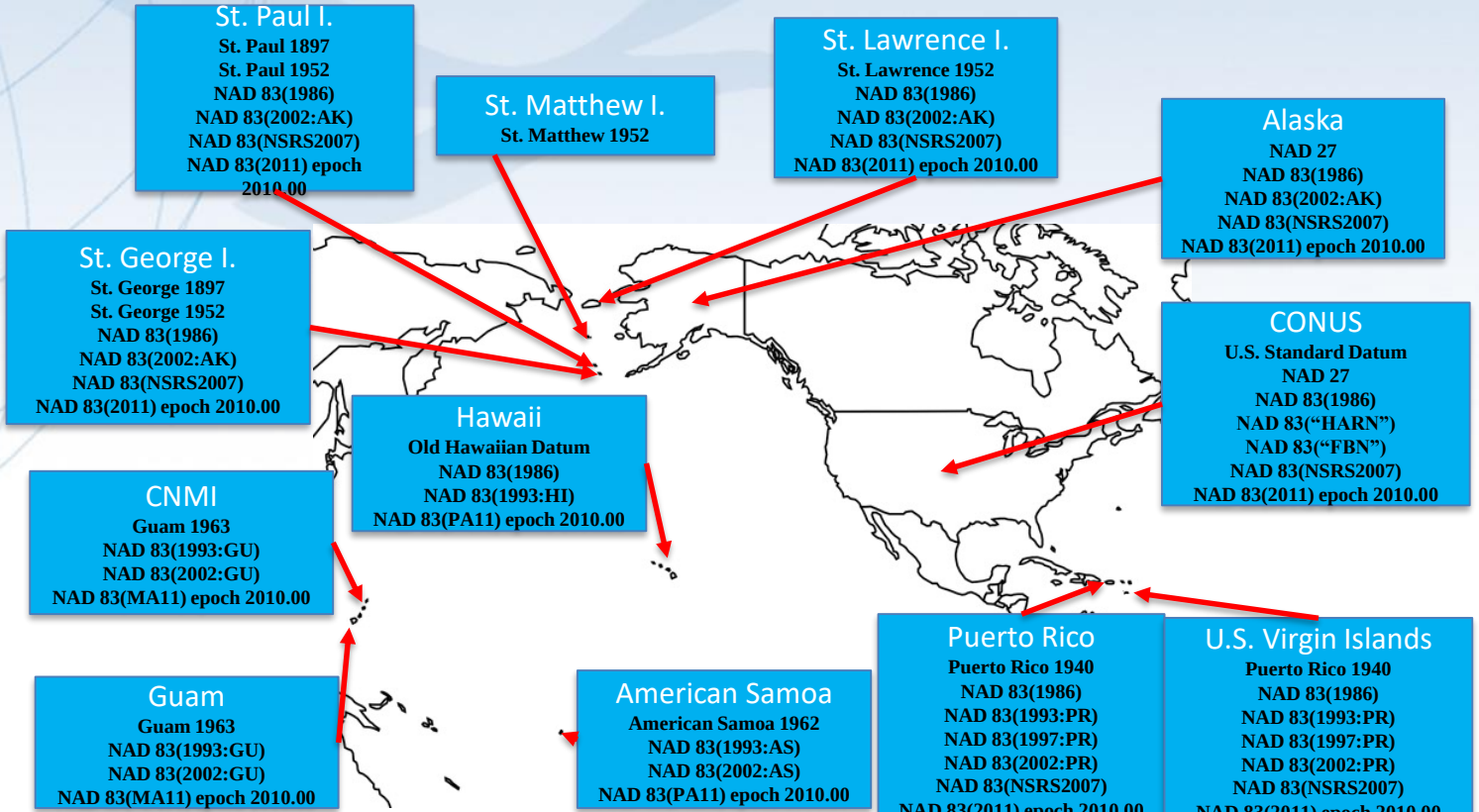
North American Terrestrial Reference Frame (NATRF2022)
Caribbean Terrestrial Reference Frame (CATRF2022)
Pacific Terrestrial Reference Frame (PATRF2022)
Marianas Terrestrial Reference Frame (MATRF2022)

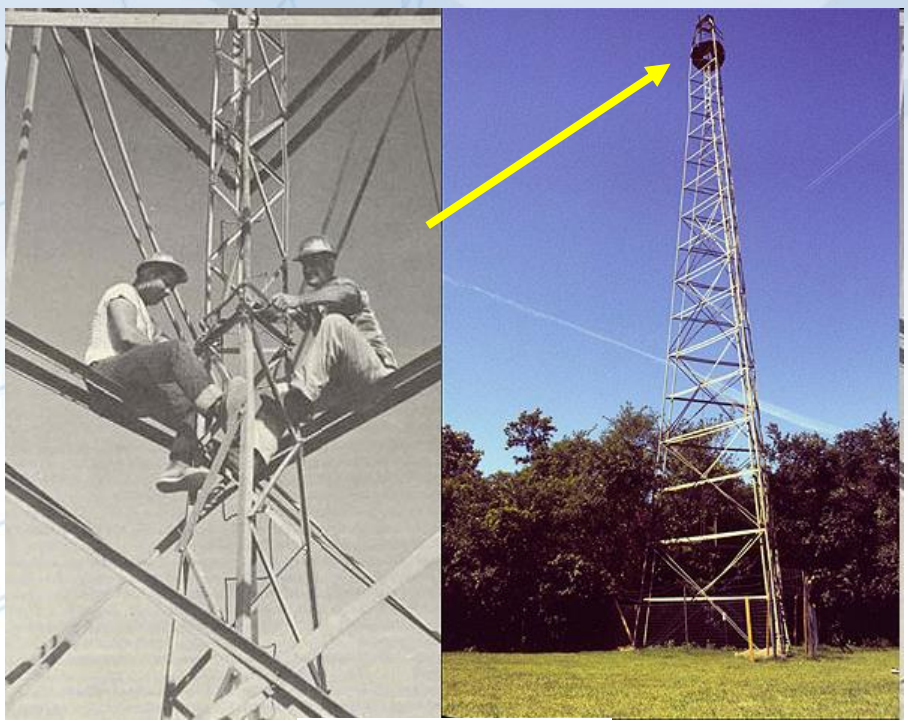
North America and Pacific Geopotential Datum (NAPGD2022)

Active Control

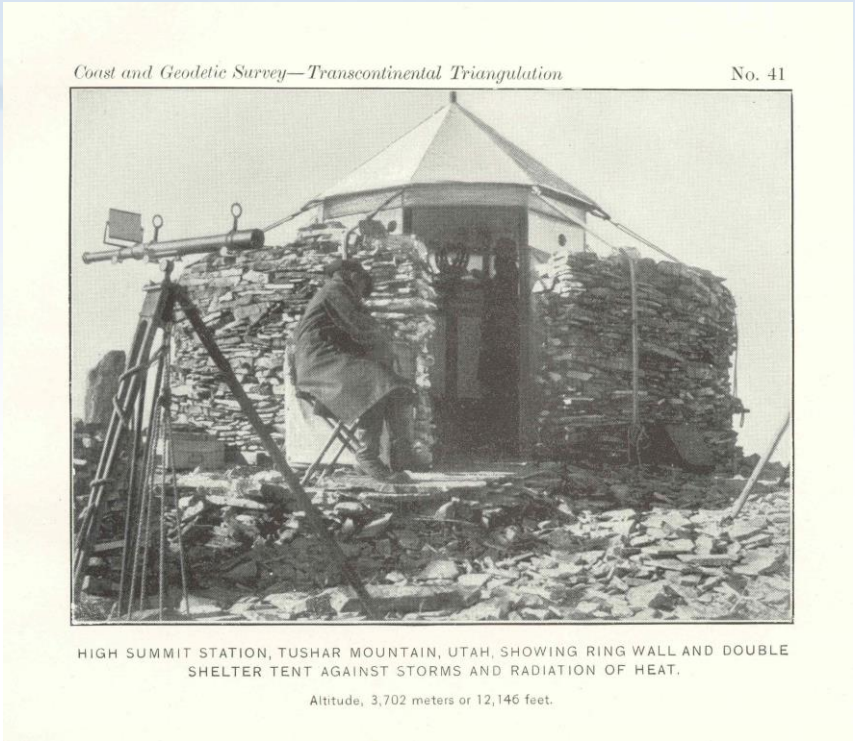


Horizontal Datums of the NSRS





STEEL BILBY TOWER



Coast and Geodetic Survey—Transcontinental Triangulation No. 41

HIGH SUMMIT STATION, TUSHAR MOUNTAIN, UTAH, SHOWING RING WALL AND DOUBLE SHELTER TENT AGAINST STORMS AND RADIATION OF HEAT.

Altitude, 3,702 meters or 12,146 feet.

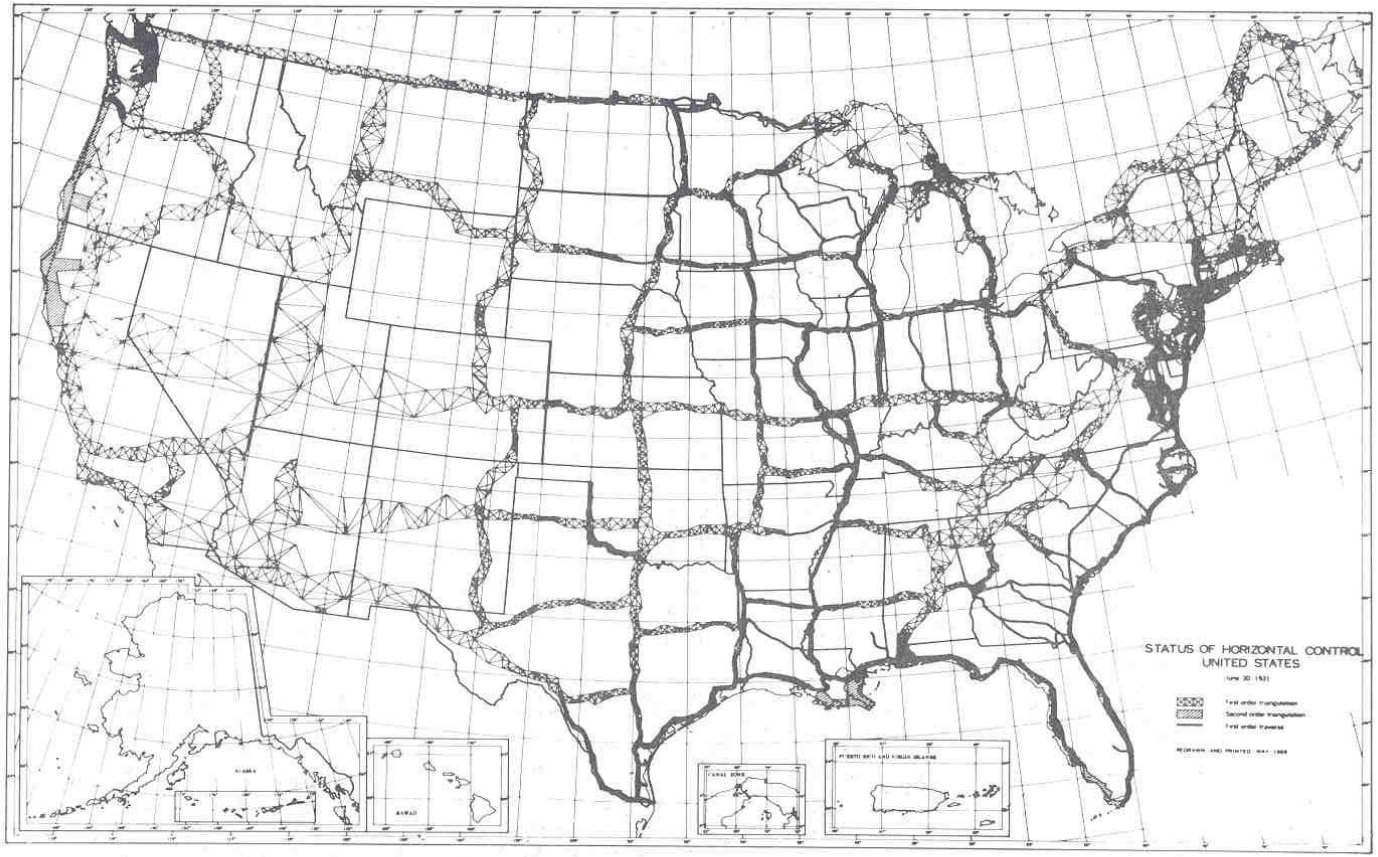
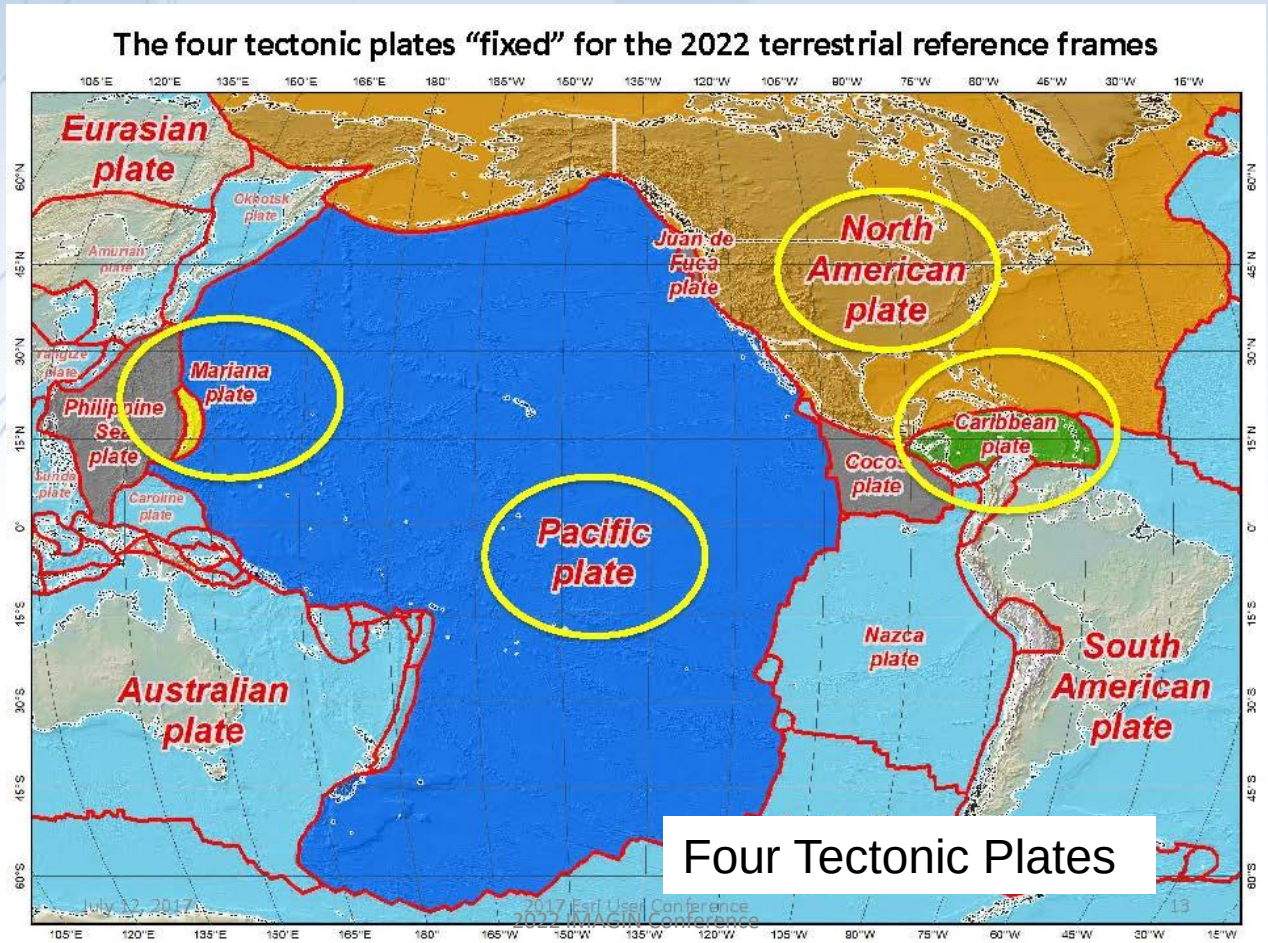


Figure 3
Horizontal Control Network of the United States June 1931

Replacing the NAD 83s

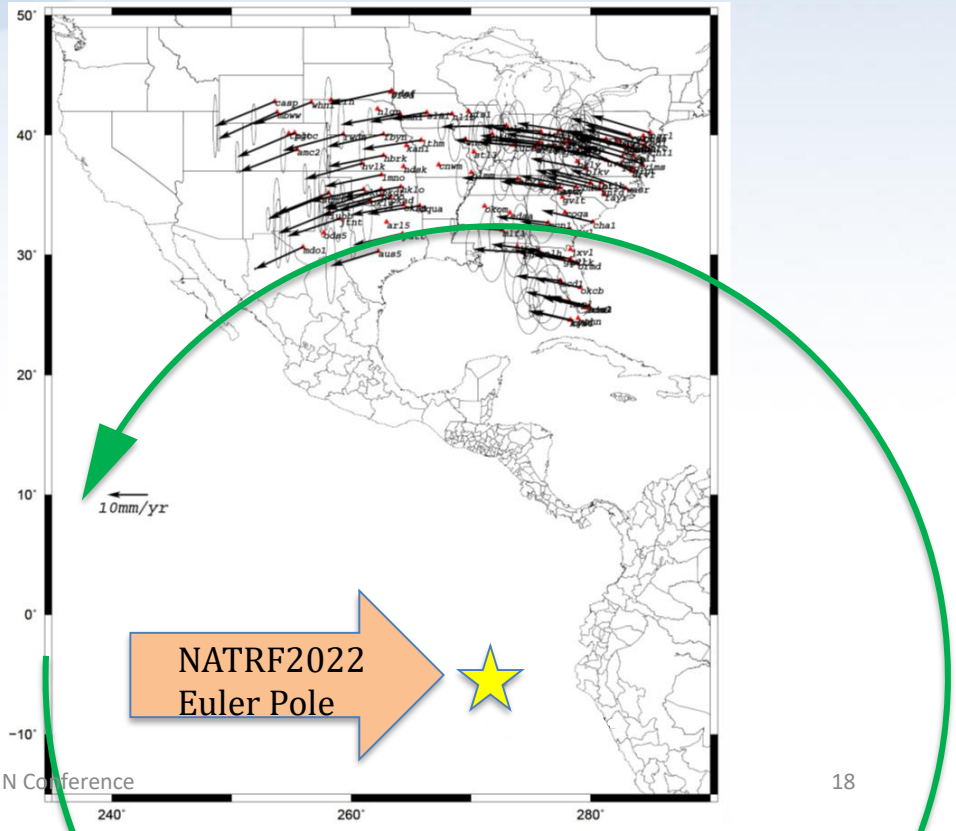
The Old	The New
NAD 83 (2011)	NATRF2022 - The North American Terrestrial Reference Frame of 2022
NAD 83 (2011)	CATRF2022 - The Caribbean Terrestrial Reference Frame of 2022
NAD 83 (PA11)	PATRF2022 - The Pacific Terrestrial Reference Frame of 2022
NAD 83 (MA11)	MATRF2022 - The Mariana Terrestrial Reference Frame of 2022



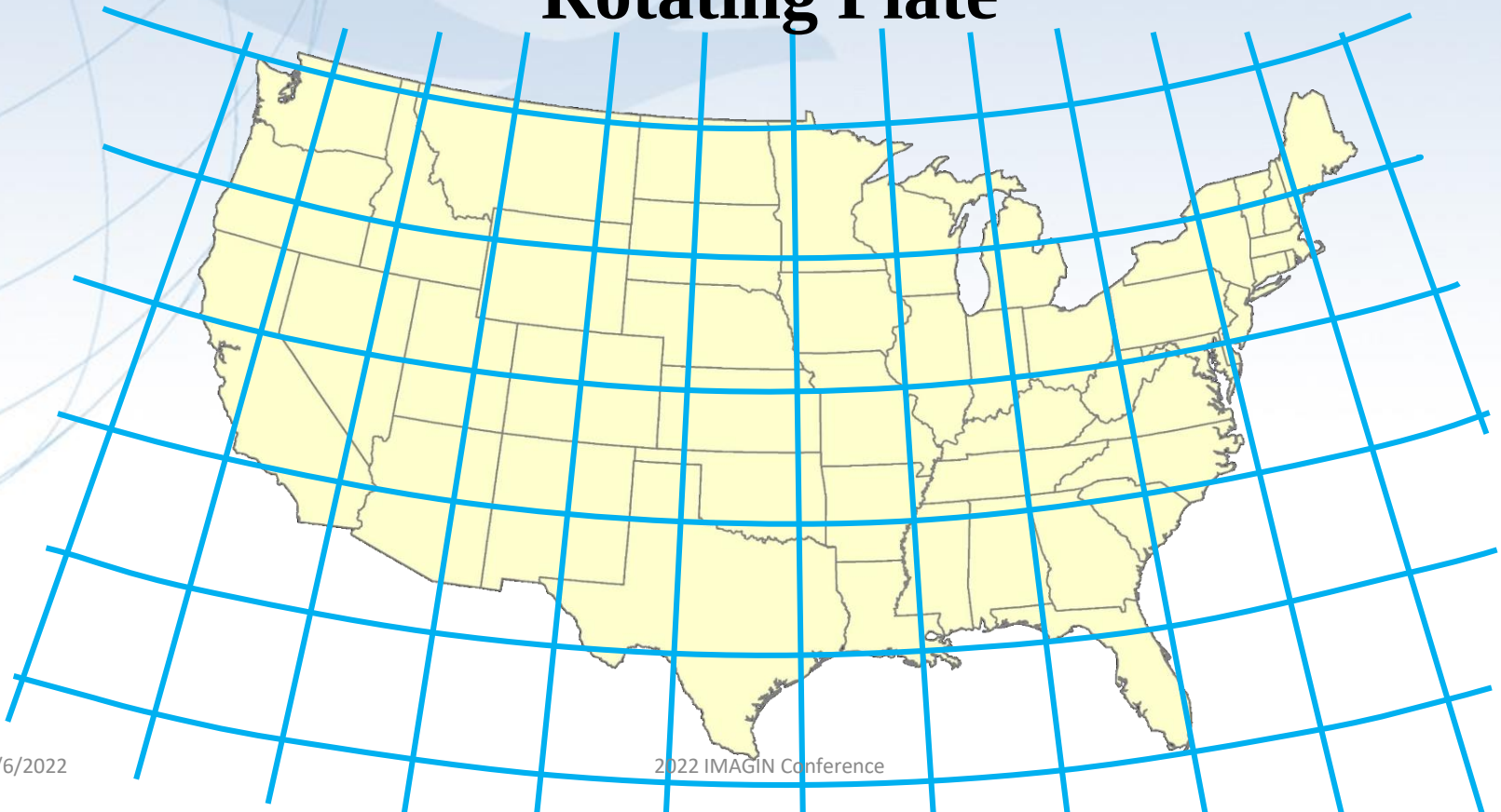
Four Tectonic Plates

Euler Poles and "Plate-Fixed"

- In the ITRF, many tectonic plates have a *dominant* motion: **rotation**
- **Euler Pole** - point about which a plate rotates (yellow star)

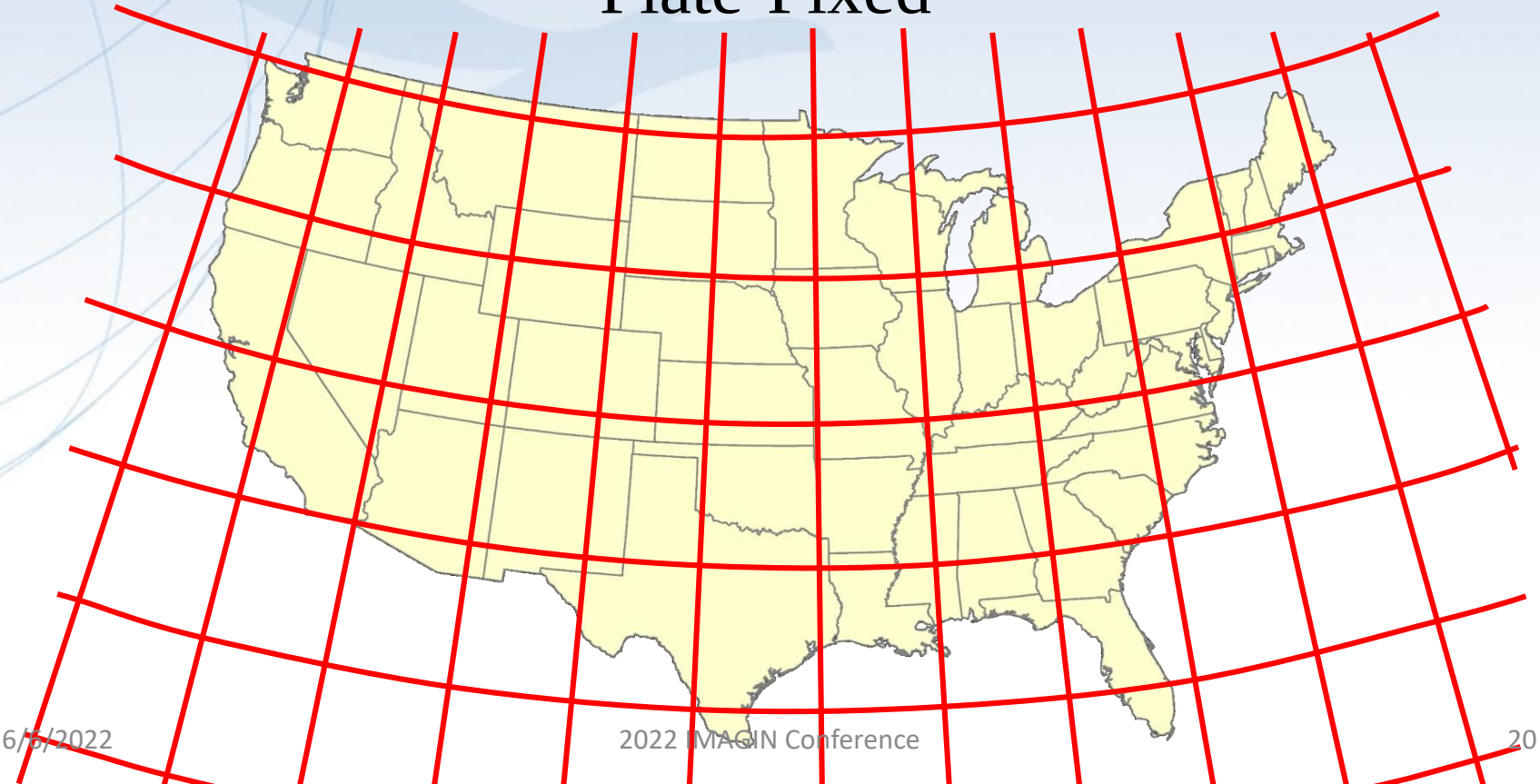


ITRF2020: Constant Frame, Rotating Plate

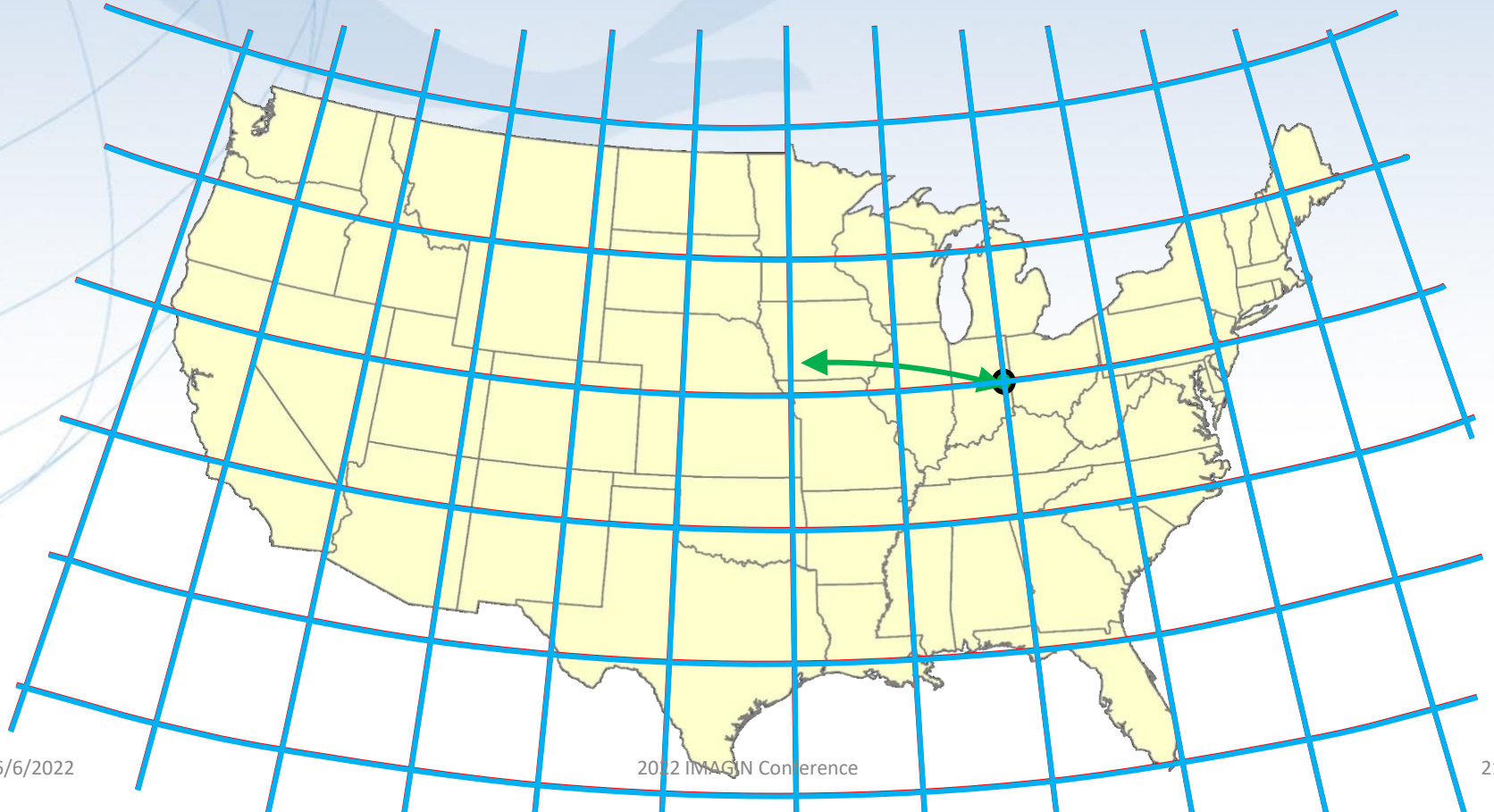


NATRF2022: Constant Frame, Rotating Plate

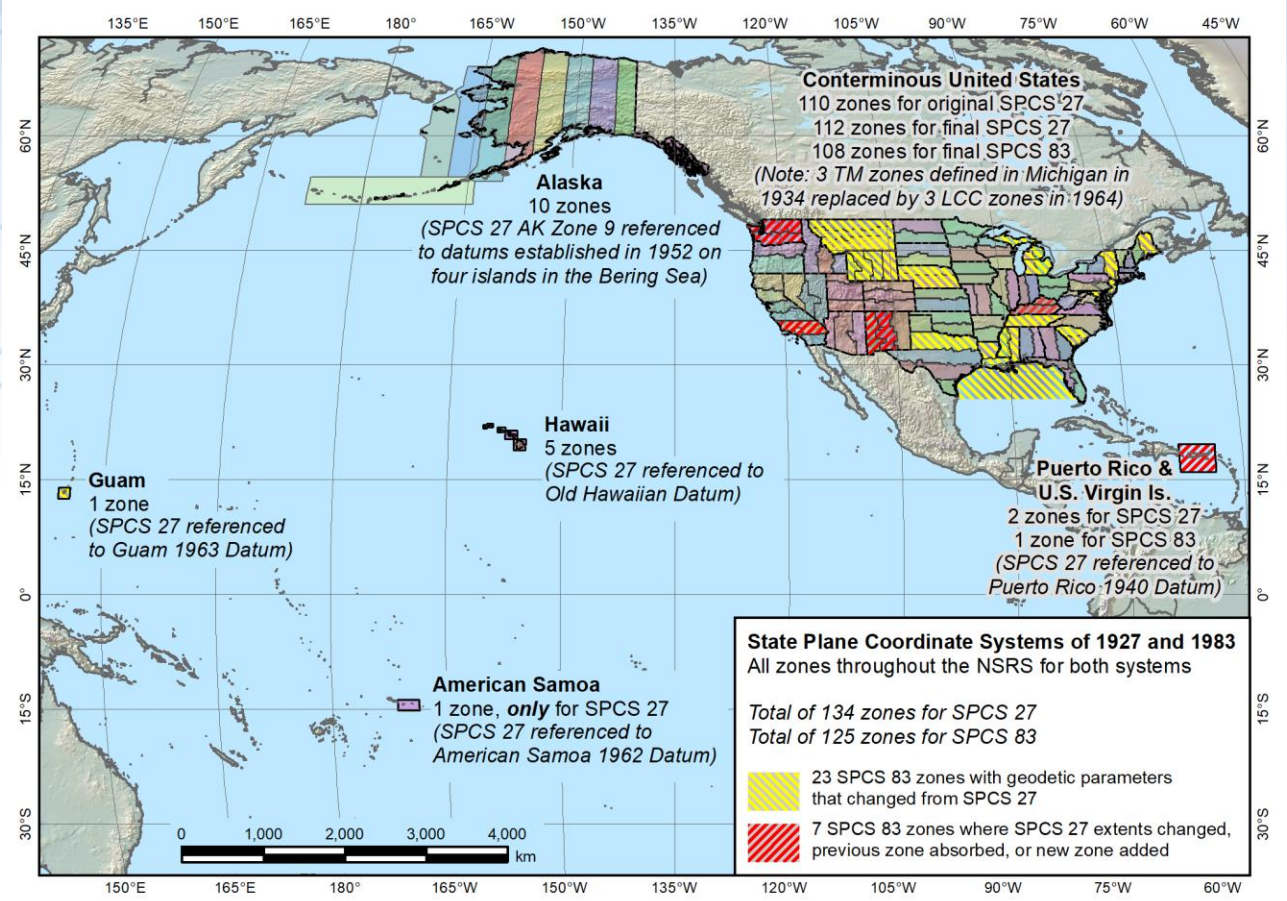
"Plate-Fixed"



ITRF2020 or NATRF2022



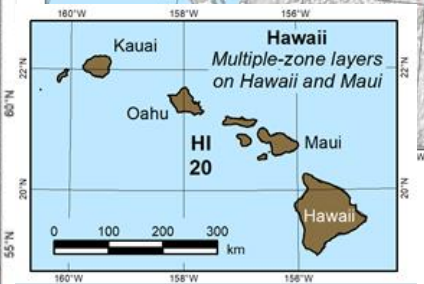
State Plane Coordinate System of 1983 (SPCS 83)



State Plane Coordinate System of 2022 (CONUS, Alaska and Hawaii)

Three territory zones not shown:

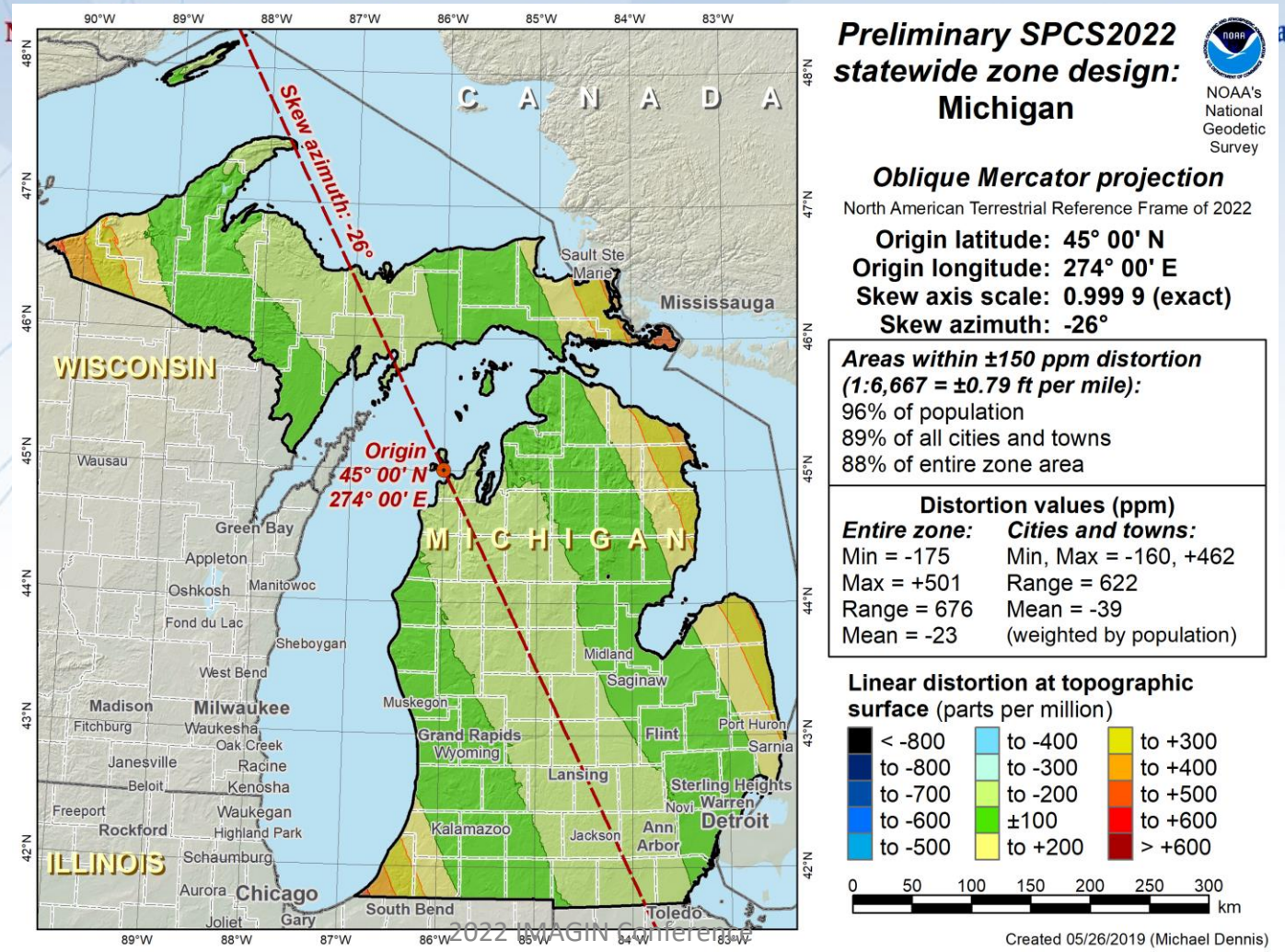
- Puerto Rico and U.S Virgin Islands
- American Samoa
- Guam and Commonwealth of the Northern Mariana Islands

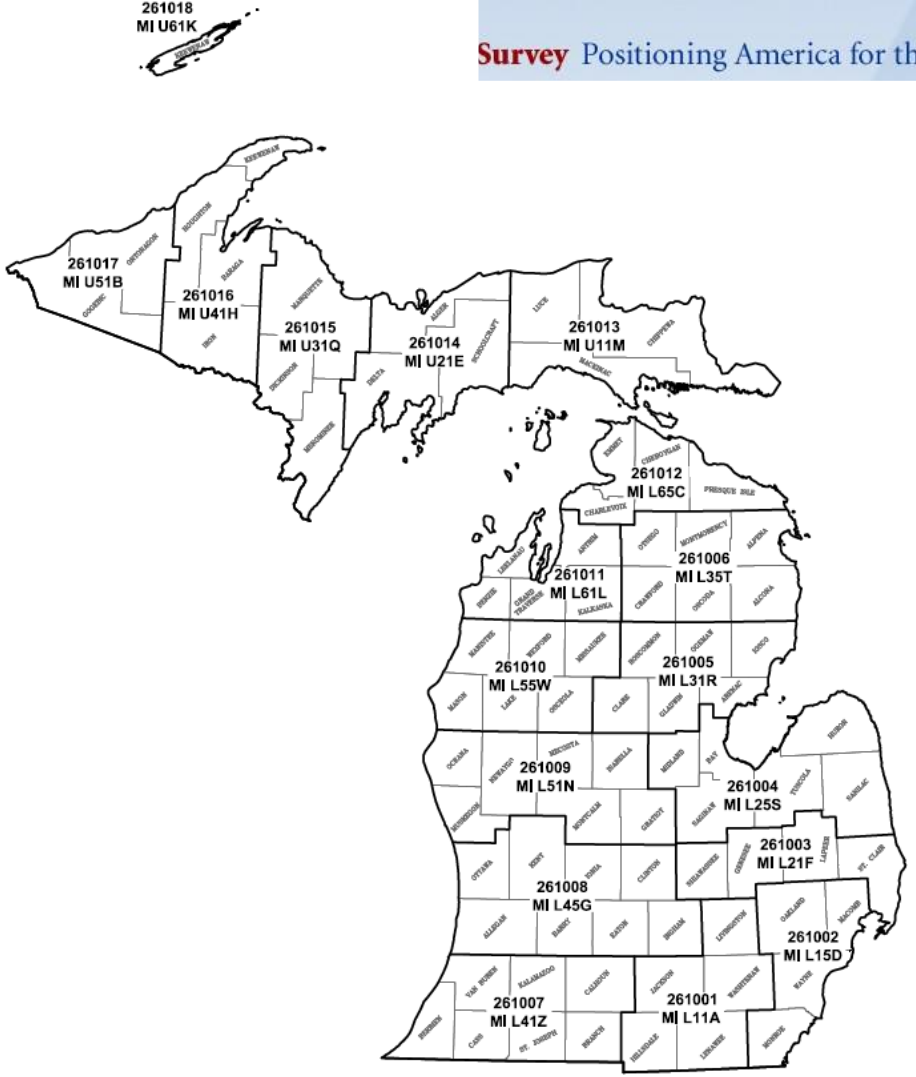


Total 965 zones (12/9/2021)

- 1 zone (18 states)
- 3 - 9 zones (14 states)
- 10 - 19 zones (6 states)
- 20 - 40 zones (11 states)
- 56 - 90 zones (7 states)

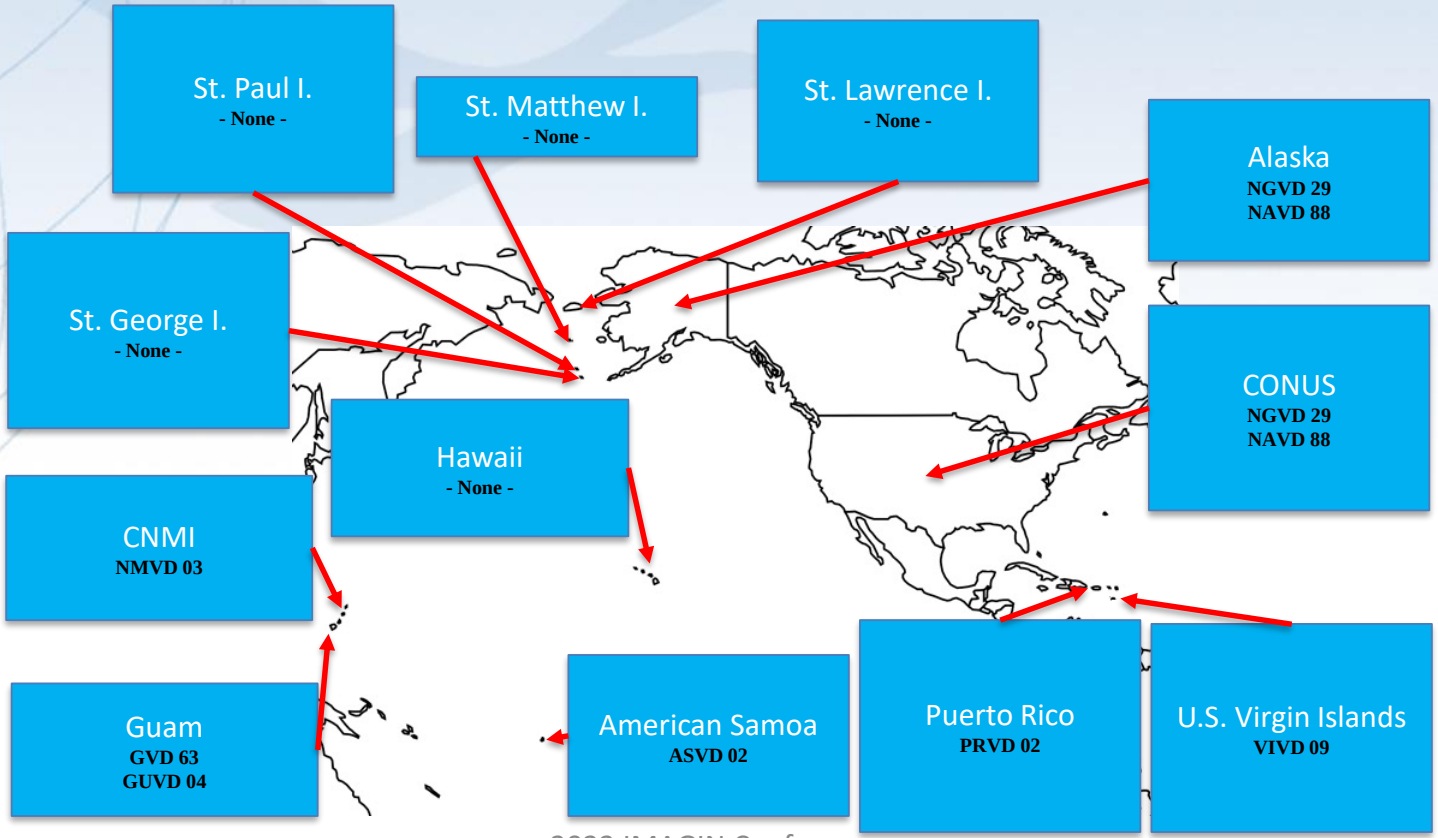
https://geodesy.noaa.gov/SPCS/


Preliminary SPCS2022 statewide zone design:
Michigan
NOAA's National Geodetic Survey
Oblique Mercator projection
North American Terrestrial Reference Frame of 2022
Origin latitude: 45° 00' N
Origin longitude: 274° 00' E
Skew axis scale: 0.999 9 (exact)
Skew azimuth: -26°
Areas within ±150 ppm distortion (1:6,667 = ±0.79 ft per mile):
96% of population
89% of all cities and towns
88% of entire zone area
Distortion values (ppm)
Entire zone:
Min = -175
Max = +501
Range = 676
Mean = -23
Cities and towns:
Min, Max = -160, +462
Range = 622
Mean = -39
(weighted by population)
Linear distortion at topographic surface (parts per million)
< -800
to -800
to -700
to -600
to -500
to -400
to -300
to -200
±100
to +200
to +300
to +400
to +500
to +600
> +600
0 50 100 150 200 250 300 km
Created 05/26/2019 (Michael Dennis)
Skew azimuth: -26°
Origin
45° 00' N
274° 00' E
CANADA
WISCONSIN
MICHIGAN
ILLINOIS
Sault Ste Marie
Mississauga
Wausau
Green Bay
Appleton
Oshkosh
Manitowoc
Fond du Lac
Sheboygan
West Bend
Madison
Milwaukee
Fitchburg
Waukesha
Oak Creek
Janesville
Racine
Beloit
Kenosha
Freeport
Waukegan
Rockford
Highland Park
Schaumburg
Aurora
Chicago
Joliet
Gary
South Bend
Muskegon
Grand Rapids
Wyoming
Midland
Saginaw
Flint
Port Huron
Sarnia
Lansing
Sterling Heights
Warren
Novi
Detroit
Kalamazoo
Jackson
Ann Arbor
Toledo
90°W
89°W
88°W
87°W
86°W
85°W
84°W
83°W
48°N
47°N
46°N
45°N
44°N
43°N
42°N

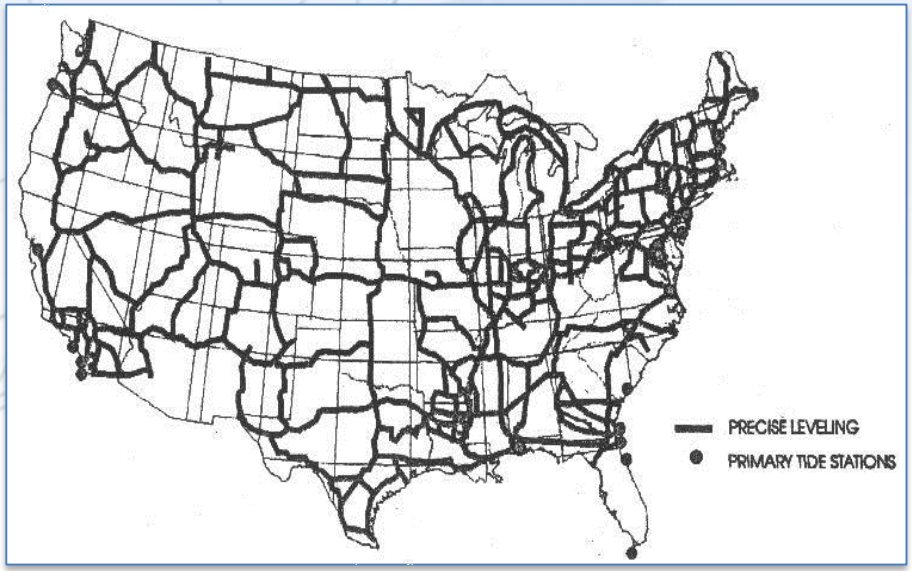


Number	Name	Abbrv
261001	ANN ARBOR	MI L11A
261002	DETROIT	MI L15D
261003	FLINT	MI L21F
261004	SAGINAW	MI L25S
261005	ROSCOMMON	MI L31R
261006	THUNDER BAY	MI L35T
261007	KALAMAZOO	MI L41Z
261008	GRAND RAPIDS	MI L45G
261009	NEWAYGO	MI L51N
261010	WEXFORD	MI L55W
261011	LEELANAU	MI L61L
261012	CHEBOYGAN	MI L65C
261013	MACKINAC	MI U11M
261014	ESCANABA	MI U21E
261015	MARQUETTE	MI U31Q
261016	HOUGHTON	MI U41H
261017	BESSEMER	MI U51B
261018	ISLE ROYALE	MI U61K

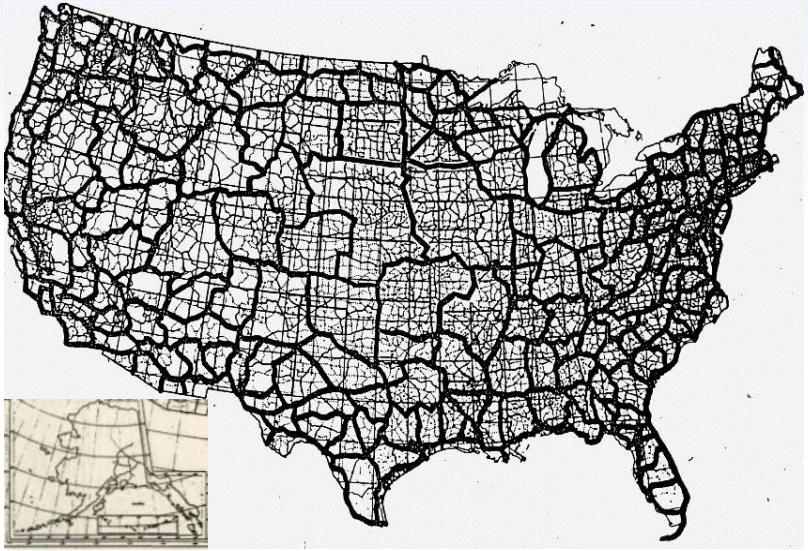
Vertical Datums of the NSRS



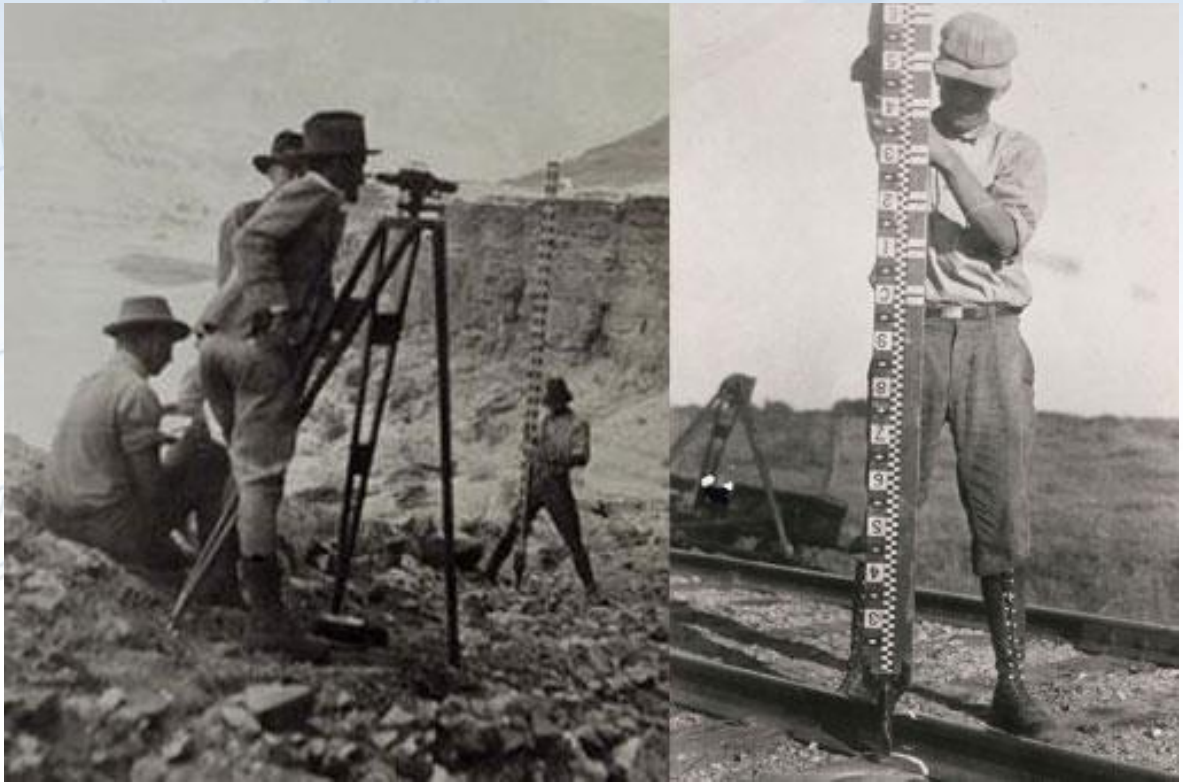
NGVD 29



NAVD 88



Leveling



Replacing NAVD 88

	The Old:
Orthometric Heights	NAVD 88
Normal Orthometric Heights	PRVD 02
	VIVD09
	ASVD02
	NMVD03
	GUVD04
Dynamic Heights	IGLD 85
Gravity	IGSN71
Geoid Undulations	GEOID18
Deflections of the Vertical	DEFLEC18

The New:

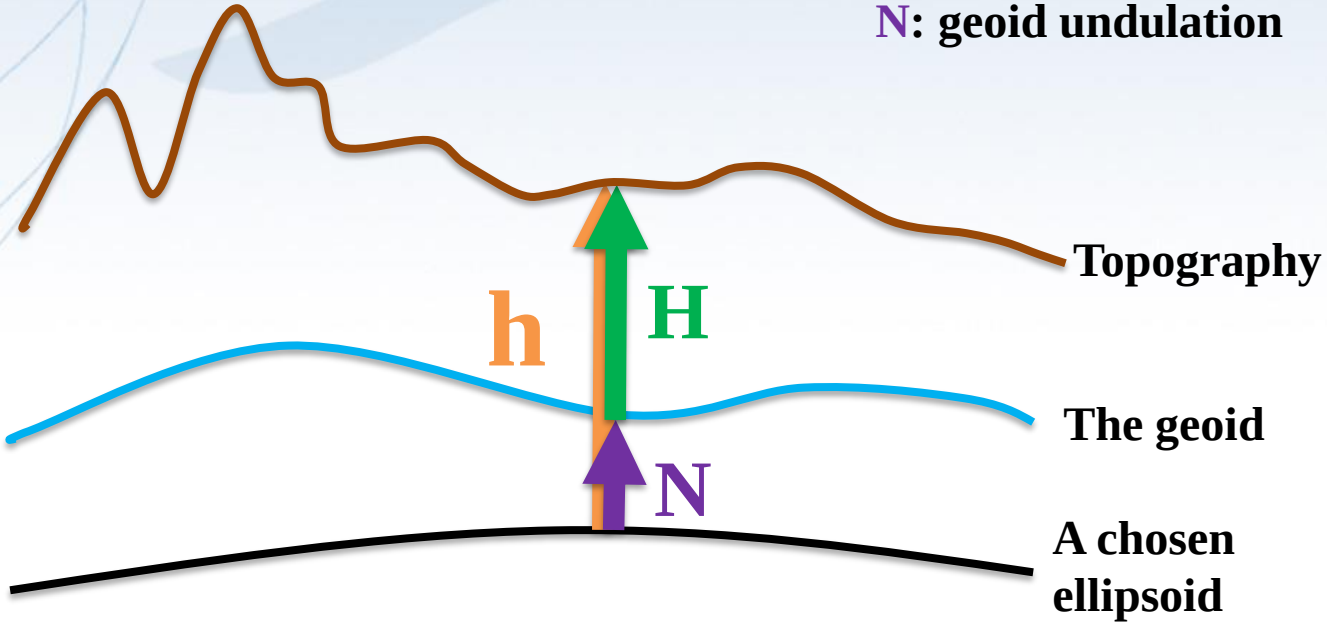
The North American-Pacific ***Geopotential Datum*** of 2022 (NAPGD2022)

- Will include geoid model GEOID2022
- Surface gravity model GRAV2022
- Deflection of the vertical model DEFLEC2022

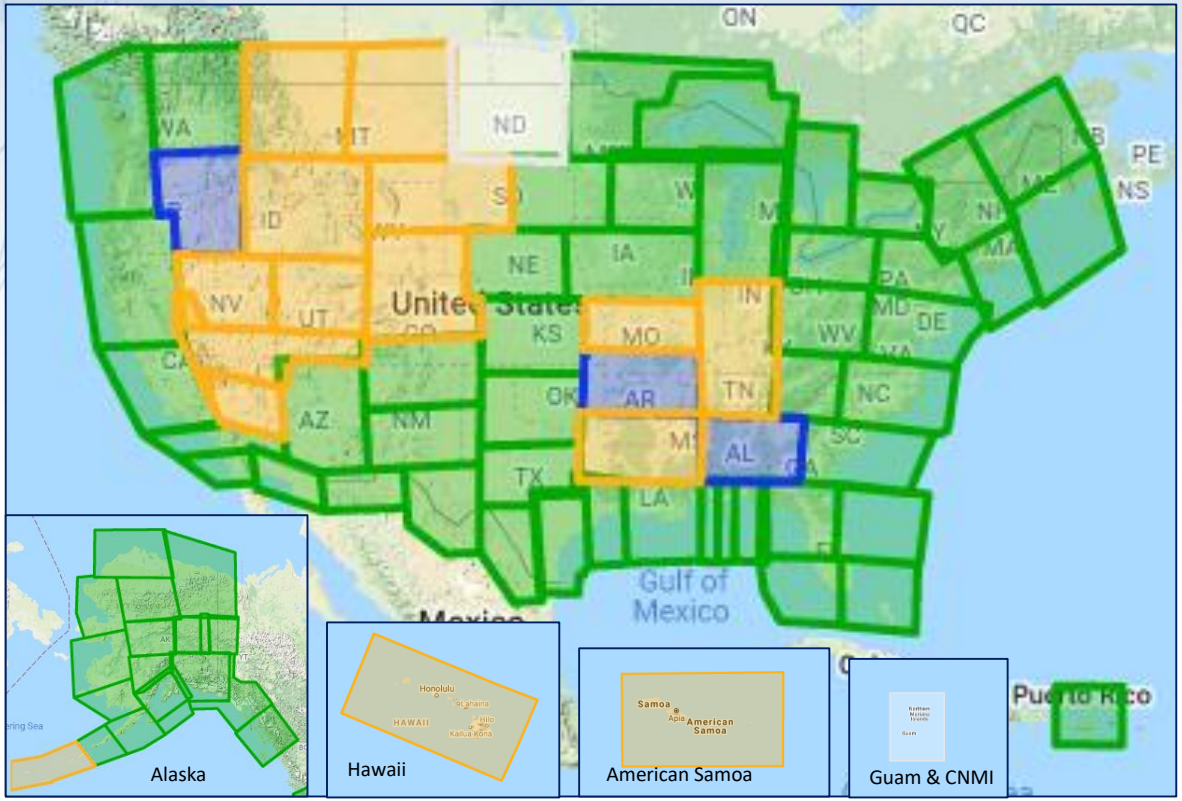
The Geoid, and Heights

$h = H + N$

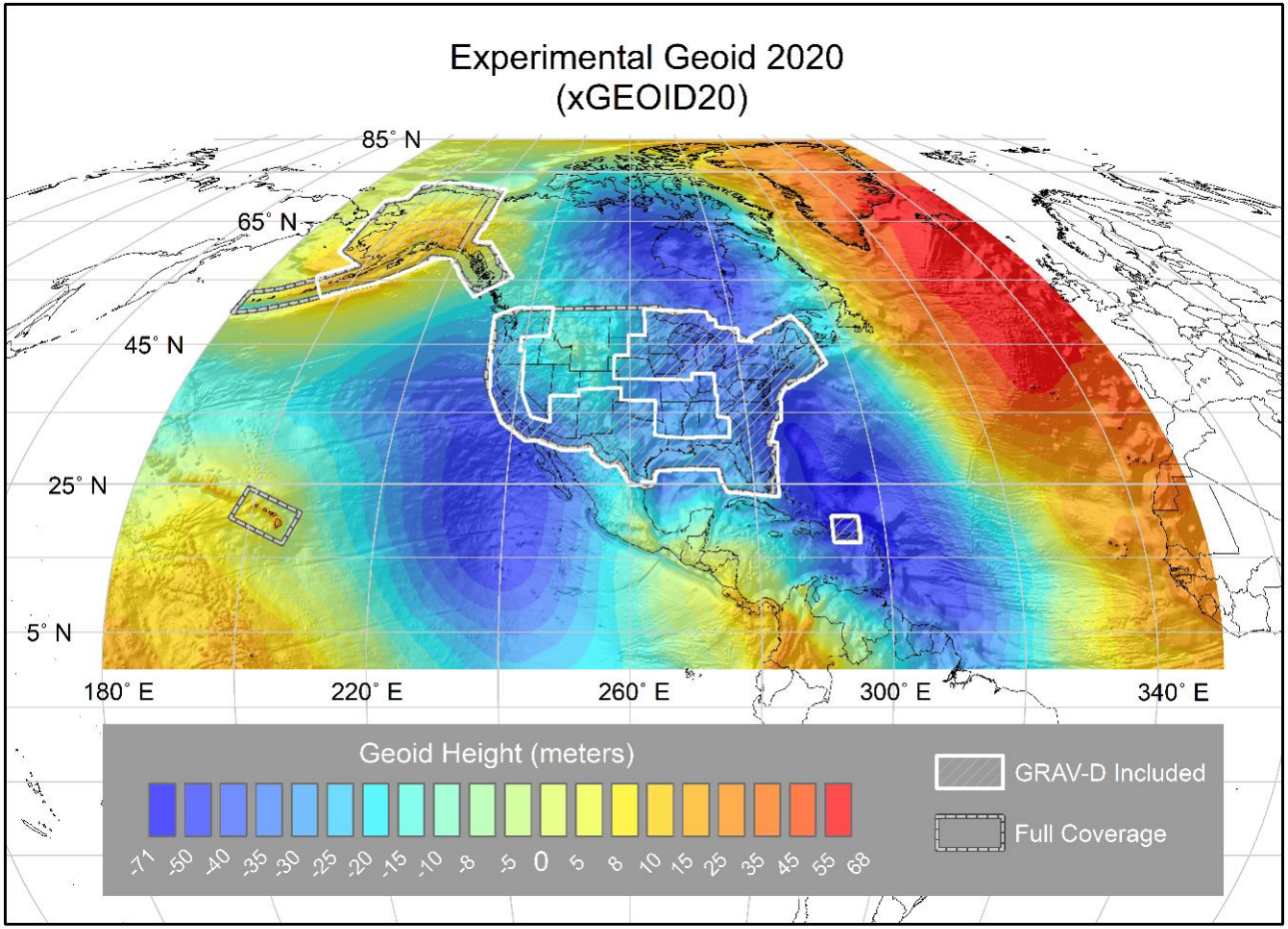
h: ellipsoidal height
H: orthometric height
N: geoid undulation



Gravity for the Redefinition of the American Vertical Datum (GRAV-D)



- 10 km data lines
- 70 km cross lines
- 20,000 ft altitude
- 230 kt flight speed

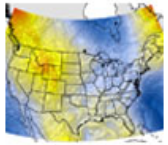

Experimental Geoid 2020
(xGEOID20)
85° N
65° N
45° N
25° N
5° N
180° E
220° E
260° E
300° E
340° E
Geoid Height (meters)
-71 -50 -40 -35 -30 -25 -20 -15 -10 -8 -5 0 5 8 10 15 25 35 45 55 68
GRAV-D Included
Full Coverage

Application Programming Interfaces (APIs)

GEOID API - The Geoid Height Service

Web service that distributes the geoid height of the NGS geoid models in a concise and portable way. The web service provides the geoid height (of a model specified by its model ID) at any given latitude and longitude. Learn more

Related Content: GEOID Models



API for Gravity Predictor using GRAV-D (airborne gravity) Data

Web service that distributes gravity data collected from the GRAV-D project in a concise, portable, and expandable way. The web service allows a user the ability to provide any geodetic location (latitude, longitude, and ellipsoid height), and the tool will output a gravity value based upon the GRAV-D data. Learn more

Related Content: GRAV-D , GRAV-D Data Blocks

API for NGS Data Explorer

Web service that distributes limited attributes from publishable data sheets for varying types of survey control. The primary purpose of this web service is to provide location and metadata for the many survey control marks throughout the nation and territories. Learn more

Related Content: NGS Data Explorer

API for NGS Coordinate Conversion and Transformation Tool (NCAT)

NGS's Coordinate Conversion and Transformation Tool (NCAT) allows users to easily convert between different coordinate systems as well as different datums, in a single step. Learn more

Related Content: NCAT

API for VDatum Tidal

VDatum Tidal API is designed to vertically transform geospatial data among a variety of ellipsoidal and orthometric vertical datums to tidal datums. Learn more

Related Content: VDatum

API for OPUS

Web service that distributes limited attributes from OPUS shared solutions. Learn more

Related Content: OPUS

https://geodesy.noaa.gov/web_services/

NGS ArcGIS Online Resources

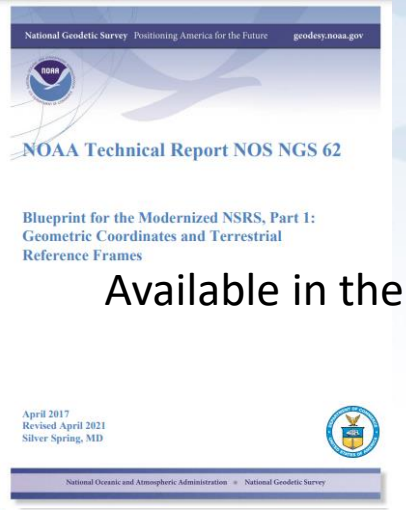
Feature Services

NGS Datasheets
NOAA CORS Network
GPS on Benchmarks Priority List
(4 layers - marks, hexagons)
GEOID18 GPS on Benchmarks
GEOID12B GPS on Benchmarks
OPUS Shared Solutions
Mark Recoveries Submitted to NGS

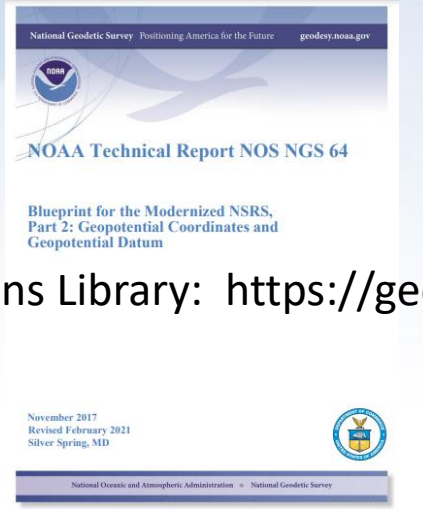
Raster Tile Services

GEOID18 Height (CONUS, PRVI)
GEOID18 Difference (CONUS, PRVI)
GEOID18 Uncertainty (CONUS, PRVI)
GEOID18 Improvements (CONUS, PRVI)

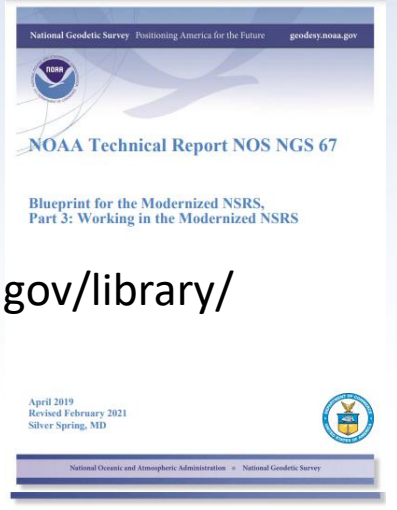
Updated blueprint documents



Geometric:
Sep 2017
Revised April 2021
NOAA TR NOS NGS 62
61 pages



Geopotential:
Nov 2017
Revised Feb 2021
NOAA TR NOS NGS 64
53 pages



Working in the Modernized NSRS:
April 2019
Revised Feb 2021
NOAA TR NOS NGS 67
133 pages

Available in the NGS Publications Library: https://geodesy.noaa.gov/library/

It's the year 2022...

NSRS Modernization: Delay

- It's official: we are delayed beyond 2022
- **How long is the delay?**
  - Unknown. Years.
- **Will names change?**
  - No, "GEOID2022", "NATRF2022", etc. will remain the same

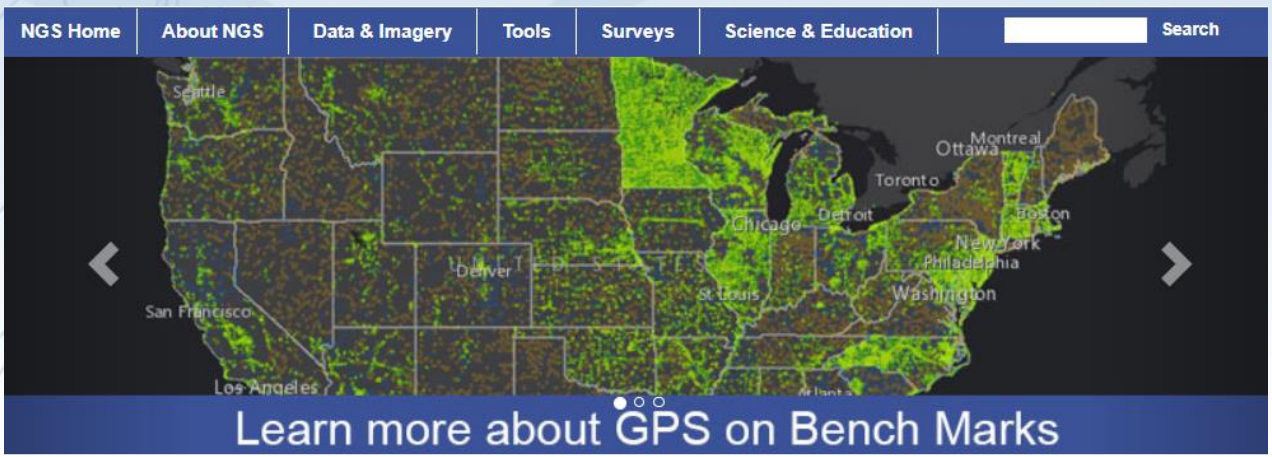
Summary

Change is coming

Coordinates will be time-dependent

Metadata is key

https://geodesy.noaa.gov/



NOAA's National Geodetic Survey (NGS) provides the framework for all positioning activities in the Nation. The foundational elements of latitude, longitude, elevation, and shoreline information impact a wide range of important activities.

Process GPS Data (OPUS) | NGS Data Explorer | Looking for Bench Marks | Conversion & Transformation (NCAT) | NOAA CORS Network | New Datums

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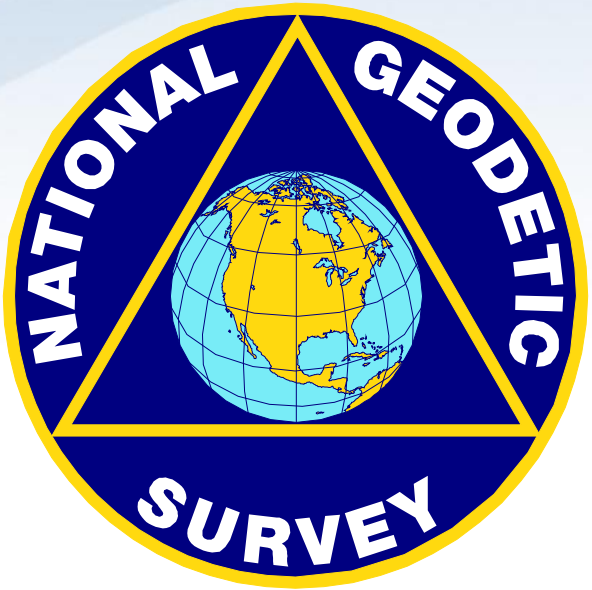
GOOD COORDINATION BEGINS WITH GOOD COORDINATES



GEOGRAPHY WITHOUT GEODESY IS A FELONY

Thank You!

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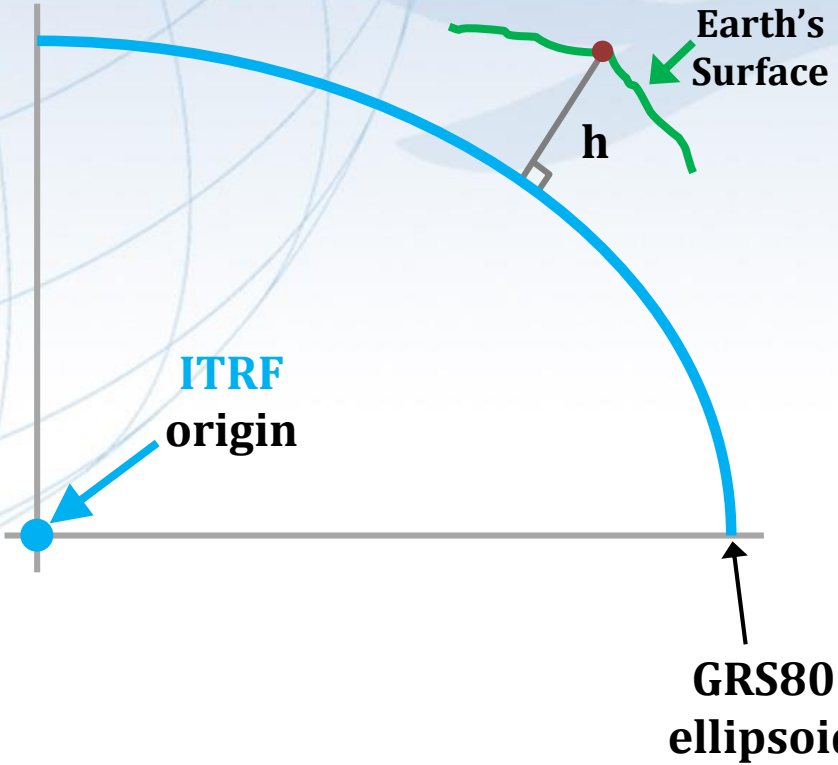
Ann Arbor, MI 48108

For more information, visit https://geodesy.noaa.gov


Earth's
Surface
h
ITRF
origin
GRS80
ellipsoid

NAVD 88 (epoch ?) to NAPGD2022 Epoch 2020.00 (estimate)