NGS: Products, Tools & Timelines for the modernized NSRS

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NOAA's National Geodetic Survey

Outline

- **Products and Tools**
  - NSRS Database
  - Data Delivery System
  - Modernized NCN
  - M-PAGES
  - LASER
  - IFDM2022
  - RECs and SECs on passive marks
  - GDX
  - OPUS 6
  - NADCON
  - VERTCON
  - NCAT/VDatum
  - SPCS2022
- Timeline

Products and Tools

NSRS Database

*The single, definitive "geospatial database" for all "quality checked"
data and metadata "collected by", used by, "or submitted to NGS"*

The NOAA CORS Network (data, coordinate functions, photos, equipment lists, etc.)

The IGS CORS Network (coordinate functions, photos, equipment lists, etc.)

Every model ever created by NGS (geoids, transformations, deformations, orbits, etc.)

Every survey ever submitted to NGS (data, reports, photos, etc.)

Every paper ever written by NGS (scientific papers, internal reports, 200+ years of historic reports, etc.)

Every coordinate ever computed by NGS (in every frame or datum, every epoch, every type of coordinate)

Did I miss something else? **It's going in too!**
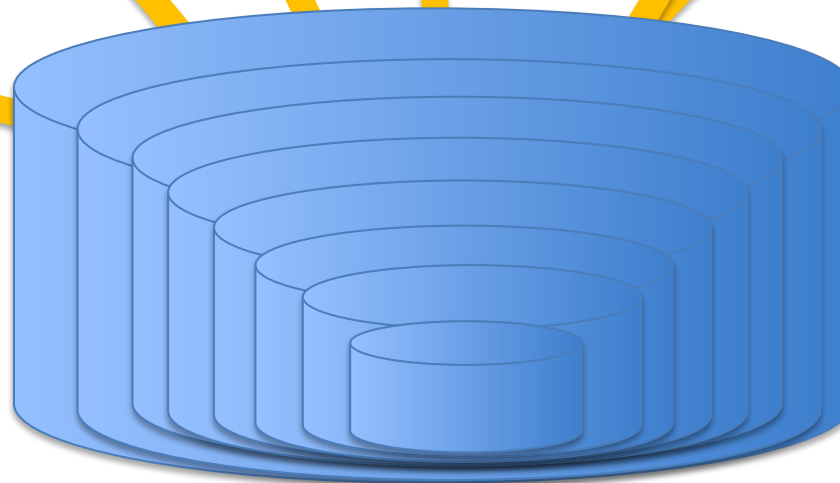
# The Data Delivery System

The single, definitive way for anyone to <u>query</u> the NSRS database and retrieve data

- Find marks near you

  – and add them to a project if you like

- Get information about a mark or station (like datasheets today, but *much* better)

- Query the NSRS Database for anything (orbits, observations, reports, etc.) but especially if it's a spatial query:

  – *Show me every mark with 'WAS' in the designation, occupied with GPS between 1995 and 2005, leveled on any date after 2000, within 50 km of a CORS and over 10 km from a state border…go!*

<u>https://devaws.nosngs.noaa/datasheets/new_datasheet/index.html</u>

The NOAA CORS Network (NCN)

- As of 2019, this is the official <u>name of the network</u> managed at NGS

  – Historically referred to as "CORS" or "the CORS"

- NGS is working hard to remove long-standing issues:

  – Customizable data availability and data quality graphs

  – Defining one physical GRP per station

  – Grading each station

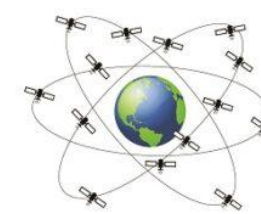 – Updated station logs
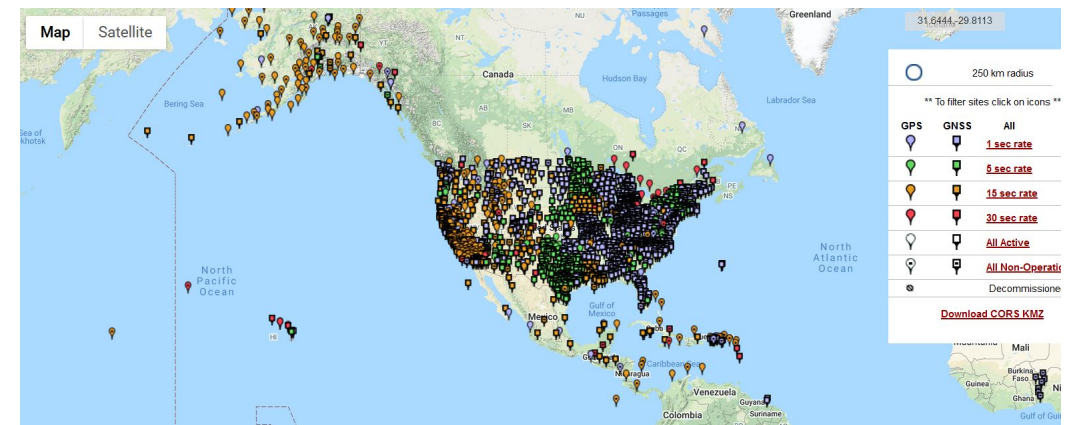
M-PAGES

- New GNSS processor

- Replaces NGS's flagship GPS-processor "PAGES"

- Can process data from any dual frequency constellation
  - Still under development
  - Built into all NGS products in the future
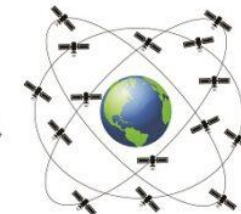

4 GNSS CONSTELLATIONS

GPS	Galileo	GLONASS	BeiDou
6 Orbital planes	3 Orbital planes	3 Orbital planes	6 Orbital planes
24 Satellite + Spare	27 Satellite + 3 Spares	21 Satellite + 3 Spares	35 Satellite + 3 GEO + 27 MEO + 3 IGSO
55° Inclination Angle	56° Inclination Angle	64.8° Inclination Angle	55° Inclination Angle
Altitude 20,200 km	Altitude 23,616 km	Altitude 19,100 km	Altitude 38,300 km, 21,500 km

LASER

- **L**east-squares **A**djustments: **S**tatistics, **E**stimates, **R**esiduals
- Replaces NGS's multiple least-squares adjustment routines
    - ADJUST, ASTA, CALIBRATE, etc.
- Replicated the 2011 national adjustment in 2 hours on a modern laptop
- GNSS vectors, angles, distances, leveling, gravity
    - Built into the modernized OPUS
    - Used for REC and SEC adjustments

IFDM2022

- **Intra-Frame Deformation Model 2022**
- Replaces HTDP's deformation model
- Models changes to geodetic coordinates over time
  - Will be equal to NADCON at REC intervals (5 or 10 years)
  - Like NADCON, should not be used to yield geodetic control, but rather map-grade, large-area changes
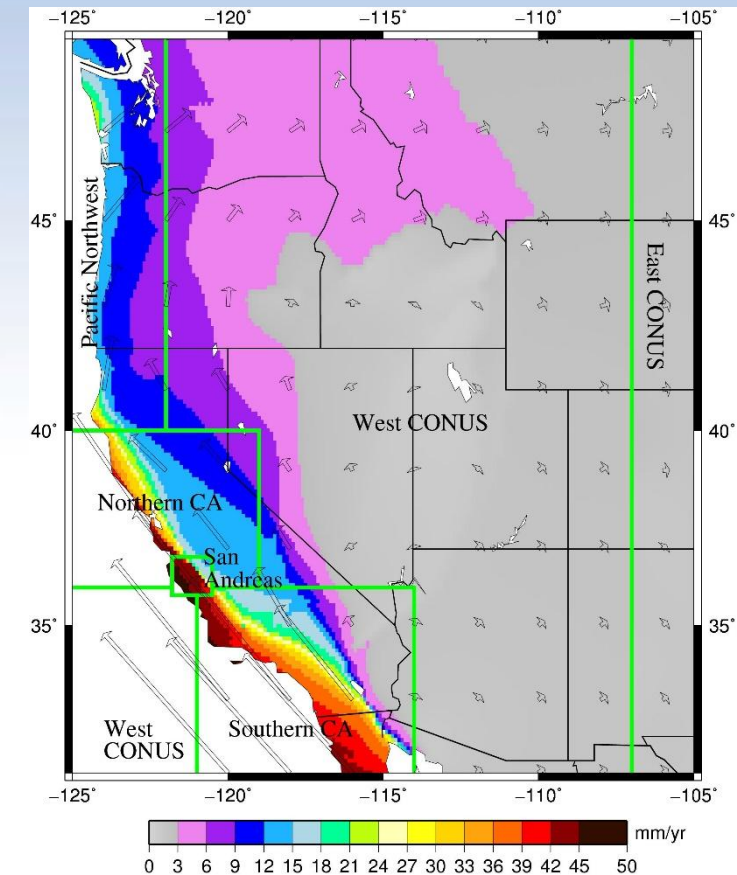
(Image of HTDP deformations)

A two-track approach to coordinates

<u>Reference Epoch Coordinates</u>

- An estimated "snapshot" of entire network

- Every 5 or 10 years

- Similar to NAD 83(2011) epoch 2010.00

<u>Survey Epoch Coordinates</u>

- Time-dependent!

- Reflects coordinates at time of observation

- Multiple SECs can show changes over time

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      <END>2018-06-29T15:51:00.00</END>
      <UTC_OFFSET/>
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Static GNSS

RTK/RTN

Classical

Leveling

Rel. Gravity

RINEX

- Upload
- Process
- Process
- Process
- Process
- Process
- Combine
- Combine
- Adjust Relative Gravity for either gravity or vertical gradients in a Gravimetric Adjustment
- Special settings for "Calibration Base Lines"
- Choose your epoch and frame
- All coordinates returned are "OPUS Coordinates"
- Submit your data to NGS for QA/QC, database loading, and improvement of future passive mark coordinates (RECs and SECs)

OPUS 6

However, NGS will first be transitioning OPUS-Projects 5.x to support the modernized NSRS.

Then we will get busy building OPUS 6.

NADCON

The single, <u>definitive</u> way to transform latitude, longitude and ellipsoid height from one frame/realization/epoch to another

CONUS	Alaska	Hawaii	Puerto Rico	USVI	Guam	CNMI	Am. Samoa
USSD	SP1897, SG1897, SP1952, SG1952, SL1952	OHD	PR40	PR40	GU63	GU63	AS62
NAD 27	NAD 27						
NAD 83 (1986)	NAD 83 (1986)	NAD 83 (1986)	NAD 83 (1986)	NAD 83 (1986)			
NAD 83 (HARN)	NAD 83 (1992)	NAD 83 (1993)	NAD 83 (1993)	NAD 83 (1993)	NAD 83 (1993)	NAD 83 (1993)	NAD 83 (1993)
NAD 83 (FBN)			NAD 83 (1997)	NAD 83 (1997)	NAD 83 (2002)	NAD 83 (2002)	NAD 83 (2002)
NAD 83 (NSRS2007)	NAD 83 (NSRS2007)		NAD 83 (NSRS2007)	NAD 83 (NSRS2007)			
NAD 83 (2011) epoch 2010.00	NAD 83 (2011) epoch 2010.00	NAD 83 (PA11) epoch 2010.00	NAD 83 (2011) epoch 2010.00	NAD 83 (2011) epoch 2010.00	NAD 83 (MA11) epoch 2010.00	NAD 83 (MA11) epoch 2010.00	NAD 83 (PA11) epoch 2010.00
NATRF2022 epoch 2020.00	NATRF2022 epoch 2020.00	PATRF2022 epoch 2020.00	CATRF2022 epoch 2020.00	CATRF2022 epoch 2020.00	MATRF2022 epoch 2020.00	MATRF2022 epoch 2020.00	PATRF2022 epoch 2020.00
NATRF2022 epoch 2025? 2030?	NATRF2022 epoch 2025? 2030?	PATRF2022 epoch 2025? 2030?	CATRF2022 epoch 2025? 2030?	CATRF2022 epoch 2025? 2030?	MATRF2022 epoch 2025?	MATRF2022 epoch 2025?	PATRF2022 epoch 2025? 2030?

These transformations will be released as part of the entire modernized NSRS

Starting here, **NADCON = IFDM2022** when applied at this exact interval (5 or 10 years)

VERTCON

The single, <u>definitive</u> way to transform orthometric* height
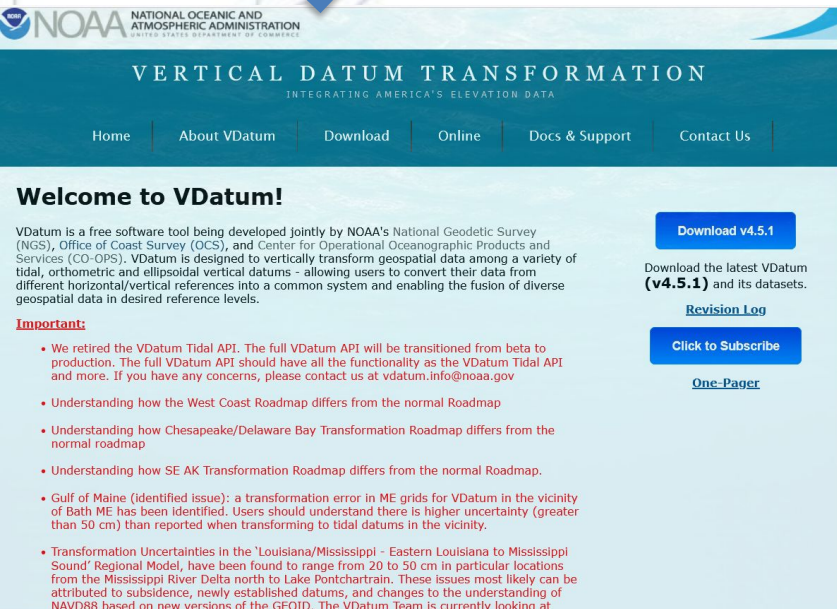*from one frame/realization/epoch to another*

CONUS	Alaska	Hawaii	Puerto Rico	USVI	Guam	CNMI	Am. Samoa
Older? (1st – 4th general adjustments??)		"Local Tidal"	"Local Tidal"	"Local Tidal"	"Local Tidal"	"Local Tidal"	"Local Tidal"
NGVD 29	NGVD 29	These transformations will be released as part of the entire modernized NSRS			GUVD 03		
NAVD 88	NAVD 88		PRVD 02	VIVD 09	GUVD 04	NMVD 03	ASVD 02
NAPGD2022 epoch 2020.00	NAPGD2022 epoch 2020.00	NAPGD2022 epoch 2020.00	NAPGD2022 epoch 2020.00	NAPGD2022 epoch 2020.00	NAPGD2022 epoch 2020.00	NAPGD2022 epoch 2020.00	NAPGD2022 epoch 2020.00
NAPGD2022 epoch 2025? 2030?	NAPGD2022 epoch 2025? 2030?	NAPGD2022 epoch 2025? 2030?	NAPGD2022 epoch 2025? 2030?	NAPGD2022 epoch 2025? 2030?	NAPGD2022 epoch 2025? 2030?	NAPGD2022 epoch 2025? 2030?	NAPGD2022 epoch 2025? 2030?

Starting here, **VERTCON = IFDM2022(h) + DGEOID2022** when applied at this exact interval (5 or 10 years)

NCAT and VDatum

*The two <u>definitive</u> ways to access all NGS coordinate conversion
and transformation tools (such as NADCON, VERTCON, SPCS, hybrid geoids)*

Master versions of all definitive
code for all tools
NADCON
VERTCON
SPCS
Etc.

SPCS2022

State Plane Coordinate System of 2022 (SPCS2022)

- *Similar to existing State Plane…*
  - Same 3 map projection types
  - Same ellipsoid (GRS 80)

Lambert Conformal Conic (LCC)
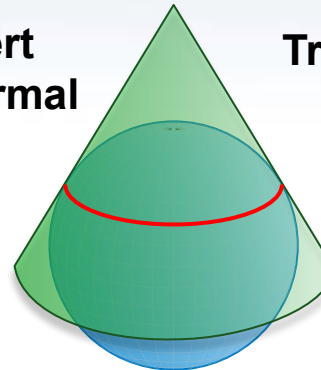
Transverse Mercator (TM)
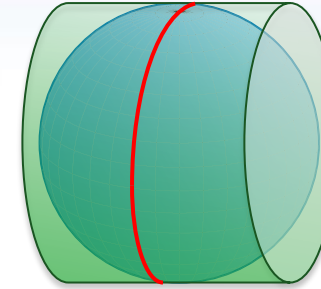
Oblique Mercator (OM)
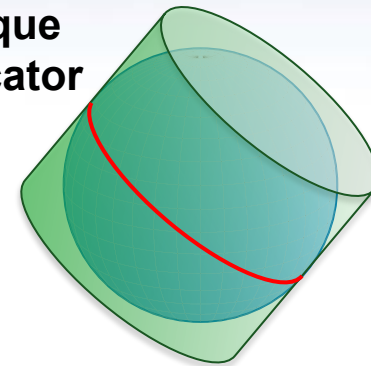
- *But different…*
  - Based on new terrestrial reference frames instead of NAD 83
  - Designed to reduce difference between "grid" and "ground"
  - Many more "zones"
  - Zones "layers" will exist in most states

Status of zone layout and designs

- **Zone "layers": Up to 3 layers per state**
    - Every state will have a statewide zone layer
    - Most states will also have a complete-coverage multiple-zone layer
    - Some states will also have a partial-coverage multiple-zone layer
- **Designs by NGS**
    - 159 zones (including 54 statewide)
    - Plus 3 "special use zones" (in more than one state)
- **Designs by state stakeholders**
    - 806 zones in 28 states; most are "low-distortion projections" (LDPs)
- **Total = 968 zones** for 56 states and territories
    - Number may decrease slightly before being finalized
- ***Compare to 125 zones for existing State Plane***

SPCS2022 zone layers

1 layer: 12 states plus 6 territories

2 layers: 28 states

3 layers: 10 states

Conterminous United States
885 zones in 48 states plus DC
1 layer (12 states plus DC)
2 layers (27 states)
3 layers (9 states)

Alaska
60 zones
3 layers

Hawaii
20 zones
2 layers on 2 islands

Guam and
Commonwealth of the
Northern Mariana Islands
1 zone

Puerto Rico &
U.S. Virgin Islands
1 zone

American Samoa
1 zone

Number of SPCS2022 zone layers per state

■	**1** *(12 states plus 6 territories)*
■	**2** *(28 states)*
■	**3** *(10 states)*
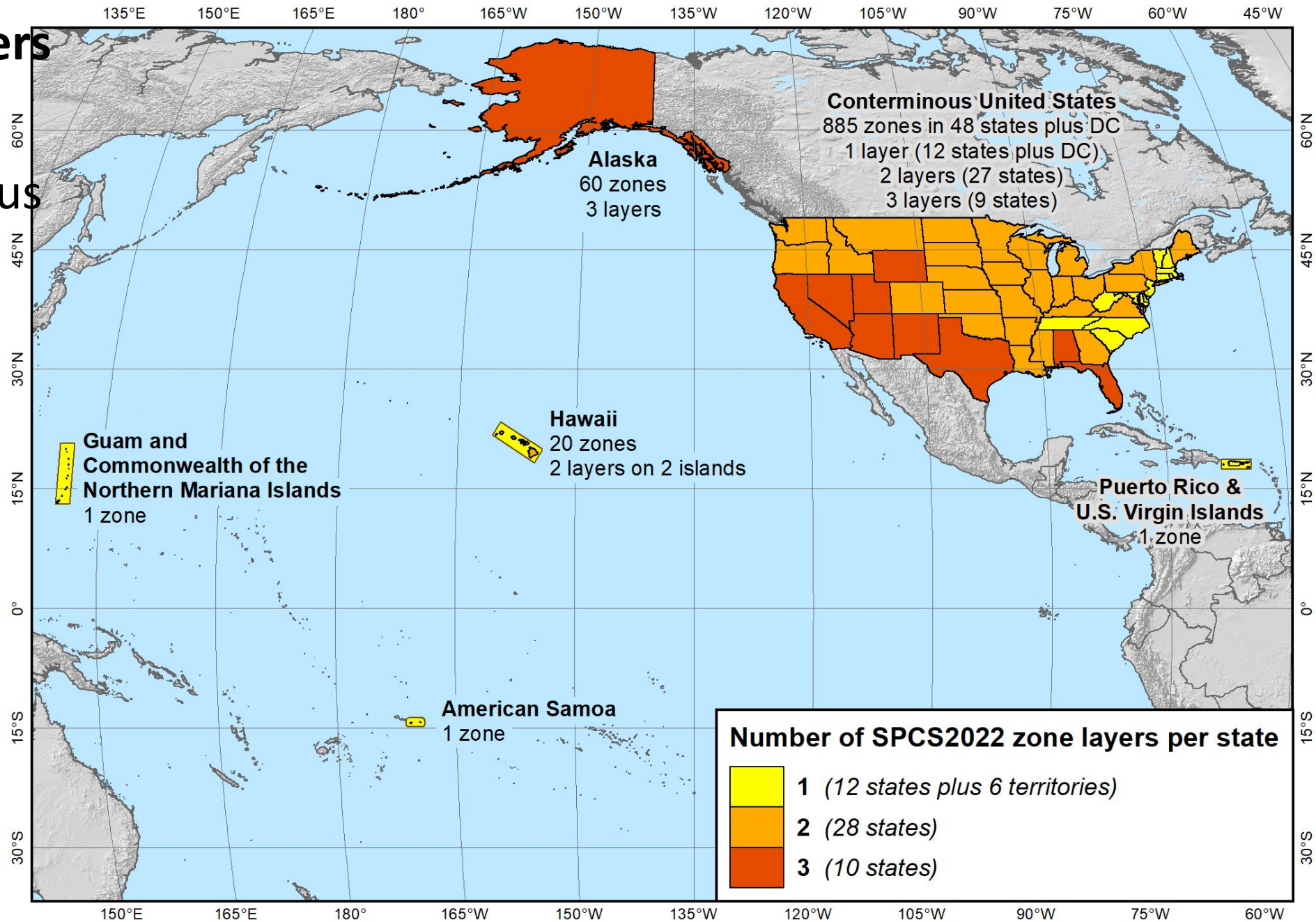
SPCS2022 zone layers

1 layer: 12 states plus 6 territories

2 layers: 28 states
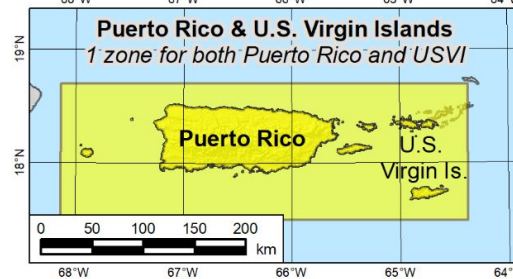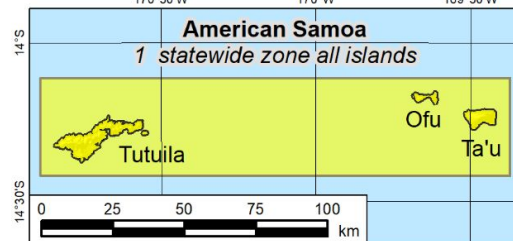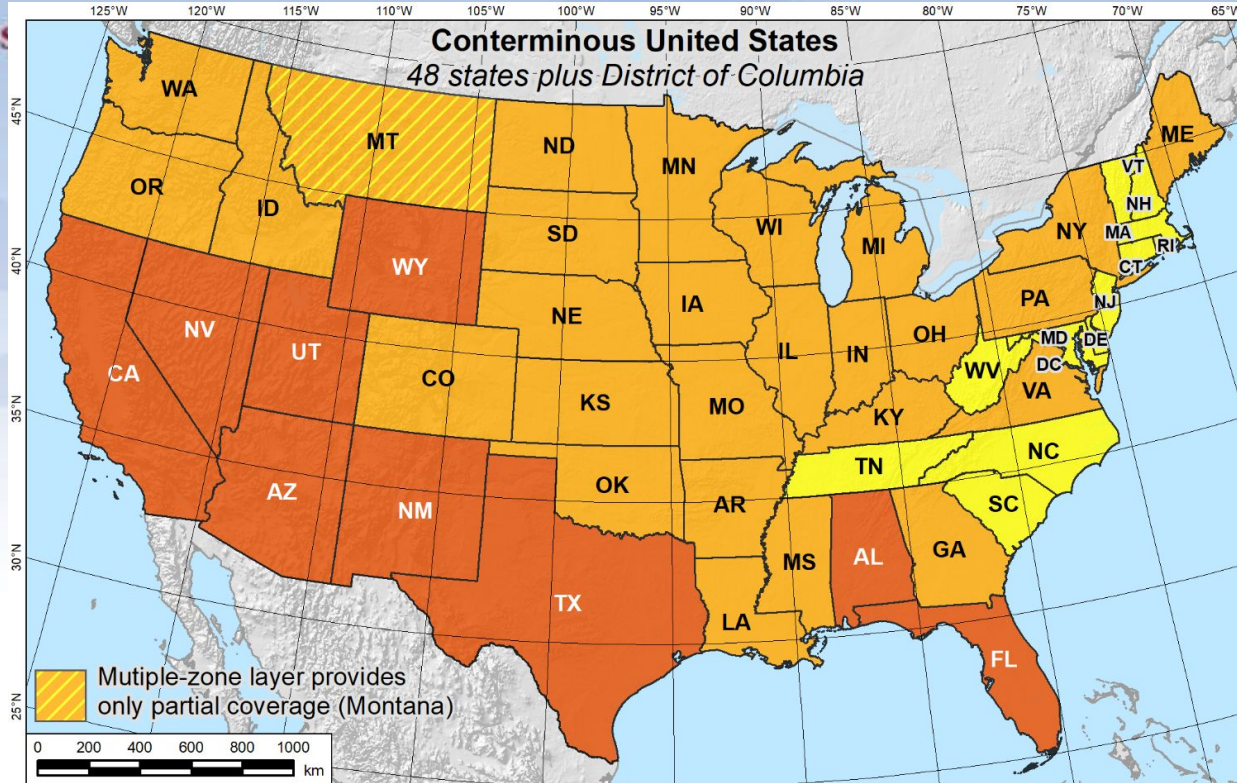
3 layers: 10 states

State Plane Coordinate System of 2022

Number zone layers
- 1 (12 states plus 6 territories)
- 2 (28 states)
- 3 (10 states)

Conterminous United States
48 states plus District of Columbia

Multiple-zone layer provides only partial coverage (Montana)

Guam and Commonwealth of the Northern Mariana Islands (CNMI)
1 zone for both Guam and CNMI

Alaska
(western Aleutian Islands not shown)

American Samoa
1 statewide zone all islands

Puerto Rico & U.S. Virgin Islands
1 zone for both Puerto Rico and USVI

Hawaii
Multiple-zone layers on Hawaii and Maui

Number of SPCS2022 zones *(preliminary)*

CONUS, Alaska, and Hawaii

Three island zones not shown:

1. Puerto Rico and U.S. Virgins Islands

2. American Samoa

3. Guam and the Commonwealth of the Northern Mariana Islands

Conterminous United States
885 zones in 48 states plus DC

State	Zones
WA	3
MT	20
ND	17
MN	33
ME	4
OR	40
ID	10
WI	60
MI	19
NY	5
SD	27
VT	
NH	
MA	
WY	6
IA	15
PA	5
CT	
RI	
NV	6
NE	26
IL	34
IN	58
OH	89
NJ	
MD	
DC	
DE	
UT	90
CO	36
KANC	
KS	20
MO	31
WV	
VA	3
CA	9
KY	8
NAVA	
AZ	63
NM	6
OK	22
AR	17
NC	
TN	
SC	
MS	3
AL	17
GA	3
TX	56
LA	3
FL	5
GULF	

Alaska *(western Aleutian Islands not shown)*

AK 60

Hawaii *Multiple-zone layers on Hawaii and Maui*

Kauai
Oahu
Maui
Hawaii

HI 20

Total 968 zones

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

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Products and Tools

Progress in the last year

- A <u>rotation model for the Mariana plate</u> released
  - Uses all available active & passive control data
  - Relative to ITRF2014
    - Will need to be updated to ITRF2020 to define MATRF2022
- An initial version of <u>M-PAGES</u> is in active testing within NGS
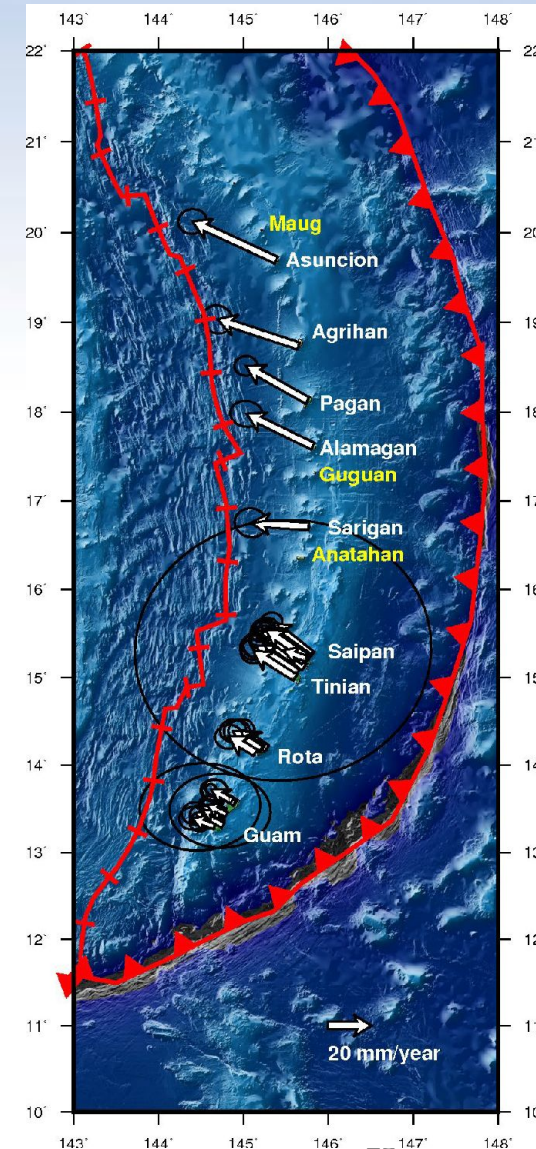
Progress in the last year: Geopotential

- <u>GRAV-D</u> flying is 96.4% done (Oct 1, 2022)

- NGS and Canada released the <u>first ever joint geoid model</u>
  - The final GEOID2022 model will also be a joint model
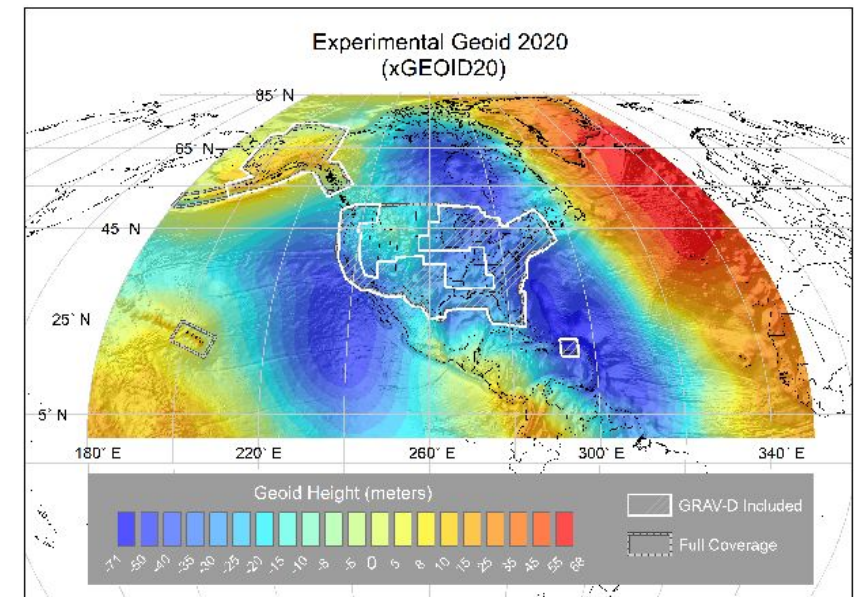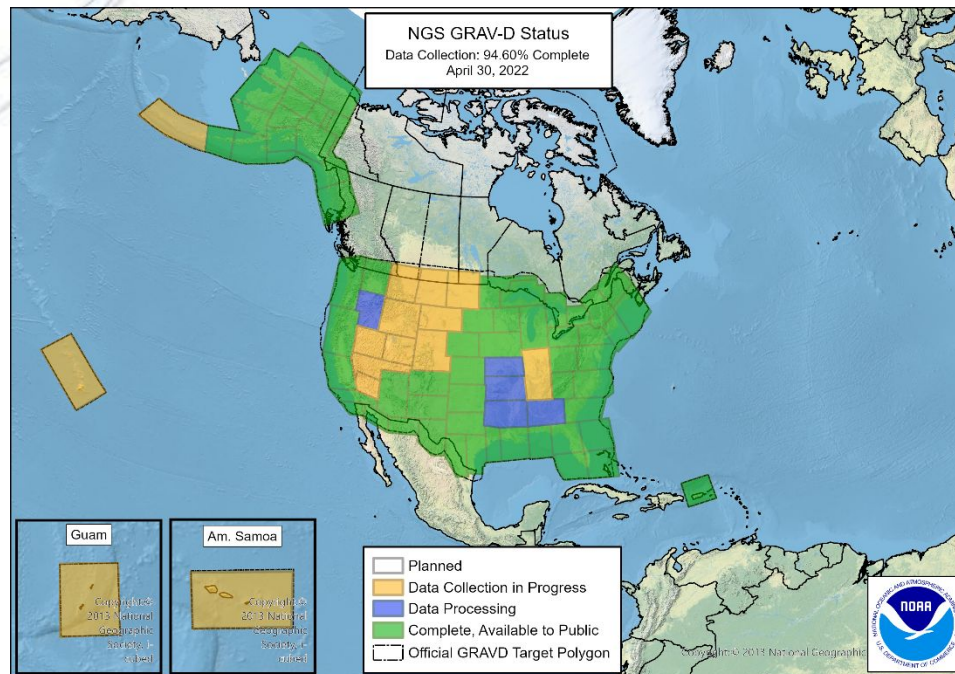
Progress in the last year: OPUS

- **GVX** (GNSS Vector Exchange) 1.0 format released
  - Being adopted by industry
    - Scheduled replacement by GDX in late 2022

- **OPUS-Projects 5.0** released
  - Works with the current NSRS
  - Supports upload of GNSS vectors in GVX format

Progress in the last year: Science

- Nine science papers in the last 2 years
  - More coming this year
  - https://geodesy.noaa.gov/library/

National Geodetic Survey *Positioning America for the Future*   geodesy.noaa.gov

NOAA Technical Memorandum NOS NGS 90

The Mathematical Relation between IFVM2022 as Expressed in ITRF2020 with IFVM2022 as Expressed in the Four Terrestrial Reference Frames of the Modernized NSRS with Dependence on EPP2022

Dru Smith
Dan Roman
Phillip McFarland
Silver Spring, MD
October 2021

National Oceanic and Atmospheric Administration   National Geodetic Survey

Progress in the last year

- **LASER:**
  - GNSS, leveling
  - Classical almost complete
  - Preparing to test a national leveling adjustment
  - Preparing to perform the first IDB + OPUS-Share combined GNSS national adjustment

Progress in the last year: Data Delivery System

- **Data Delivery System:**
    - Replacement for current datasheets has been prototyped
    - A new CORS "datasheet" is nearly complete

What to look for by the end of 2022

- OPUS-S to be updated to M-PAGES
- Science papers focusing on least squares adjustments
- An "alpha" set of 2020.00 geometric RECs

SPCS2022 timeline

- **Timeline**
  - Review of stakeholder submittals (DONE)
  - Late 2022-Early 2023: Preliminary designs for stakeholder review
  - Mid-2023: Finalize all zone designs
- **Other things in 2023**
  - Provide machine-readable definitions (e.g., Well-Known Text)
  - Provide zone extent envelopes and polygons
  - Modify NGS algorithms (e.g., 1-parallel Lambert, centered Oblique Mercator)
  - Document new projection algorithms
- **Release with rollout of modernized NSRS**
  - Final definitions available by late 2023
  - Release with new "datums" in 2025

Re-prioritization: a "data first" approach

Re-prioritization

- There are 33 active projects within NGS explicitly dedicated to NSRS modernization
  - In an agency of ~200 people….resources are spread *thin*
- Meanwhile the current NSRS slowly deteriorates
  - Marks subside without checking
  - CORSs drift away from their published coordinate functions
  - The passive control network deviates from active control

Re-prioritization

- NGS has recently decided to release all of the modernized NSRS **data** before we have fully completed all support **tools**

- ***If we do not take this approach, we are not likely to see the modernized NSRS defined and released until 2030***

Data

- ## Upon release, the modernized NSRS will consist of this *data*:
  - The NOAA CORS Network (NCN) operating on **ITRF2020**
  - **NATRF2022, PATRF2022, MATRF2022, CATRF2022** defined relative to ITRF2020
  - **NAPGD2022**, including:
    - GM2022, GEOID2022, DEFLEC2022, GRAV2022
  - Geometric (XYZ / $\varphi\lambda h$) and orthometric (H) **reference epoch coordinates** (RECs) at 2020.00 at those passive control with the observations to support such coordinates
  - Geometric (XYZ / $\varphi\lambda h$) and orthometric (H) **survey epoch coordinates** (SECs) at survey epochs between about 1994 and 2020 at those passive control with the observations to support such coordinates
  - **State Plane Coordinates** of 2022 (SPCS2022), plus UTM and USNG
  - **NADCON**
    - Connecting NAD 83(2011/MA11/PA11) epoch 2010.00 to N/P/M/CATRF2022 epoch 2020.00
  - **VERTCON**
    - Connecting NAVD 88, PRVD02, ASVD02, NMVD03, GUVD04 and VIVD09 to NAPGD2022 epoch 2020.00

Tools

- At a minimum, NGS is targeting these tools upon release:
  - A **DDS** capable of yielding:
    - RECs on some kind of datasheet
    - Information on CORSs
  - A downloadable version of **LASER**
  - **A browser-based online multi-GNSS service:**
    - Like OPUS-S
    - Like OPUS-Projects 5.x
  - **NCAT** and **Vdatum** capable of invoking **NADCON, VERTCON** and **SPCS2022**

What will have to wait…

- Promises we intend to keep, but not until after the initial release of the modernized NSRS include:

    – Integrating leveling, classical data and gravity into OPUS

    – Full integration of all old tools into NCAT and Vdatum

    – SECs for pre-1994 (AKA "pre-NCN") years, plus SECs for post-2020

Timeline

Timeline

- Resources are being diverted from tool building to the assurance of quality ***data*** first and foremost

- As such, based on this new approach, NGS anticipates the release of all data, and limited tools, by the **middle of 2025**.
  - Some of this requires the "stars to align", such as NGS receiving congressionally-approved IIJA money to accelerate GRAV-D

- Work on additional tools will continue in the out-years

Thank you!

Questions?