NATIONAL ACADEMIES Sciences Engineering Medicine

TRB TRANSPORTATION RESEARCH BOARD

TRB Webinar: Resolving Ambiguities Between 3D Virtual Models and the Real World

December 18, 2024

11:00 AM – 12:30 PM

PDH Certification Information

1.5 Professional Development Hours (PDH) – see follow-up email

You must attend the entire webinar.

Questions? Contact Andie Pitchford at TRBwebinar@nas.edu

The Transportation Research Board has met the standards and requirements of the Registered Continuing Education Program. Credit earned on completion of this program will be reported to RCEP at RCEP.net. A certificate of completion will be issued to each participant. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the RCEP.

ENGINEERING RCEP REGISTERED CONTINUING EDUCATION PROGRAM

Purpose Statement

This webinar will raise awareness within the department of transportation (DOT) community about the critical need to resolve ambiguities between virtual 3D models and real-world conditions.

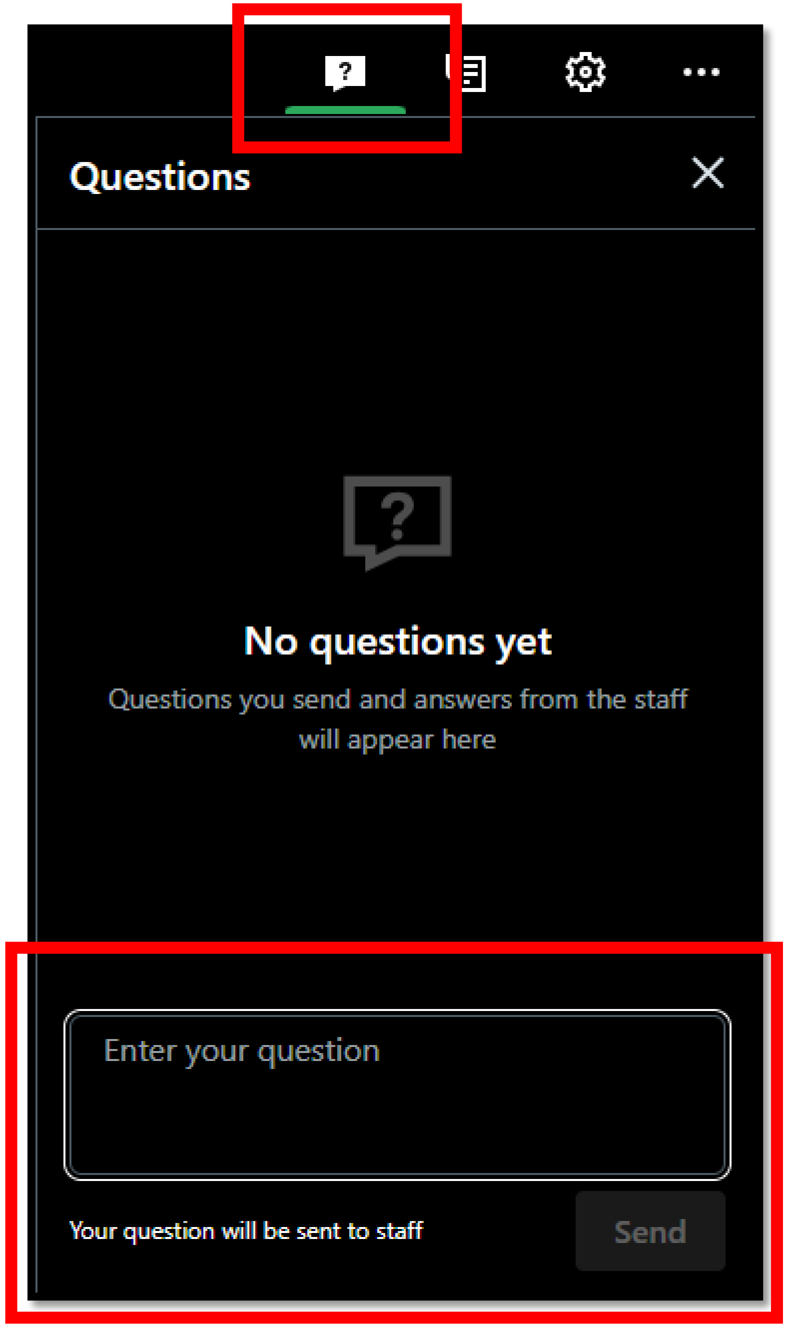
Learning Objectives

At the end of this webinar, you will be able to:

- Address and accommodate the adoption of current 3D CADD technology with an awareness of the associated limitations
- Understand how ambiguities will cause problems with the digital delivery process and create inefficiencies in future asset operations and maintenance
- Resolve ambiguities to provide a solid real world reference frame foundation that supports digital delivery to operations and maintenance that involves automation technologies in conjunction with analytical simulation and modeling

Questions and Answers

- Please type your questions into your webinar control panel
- We will read your questions out loud, and answer as many as time allows



Today's presenters

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Infotech

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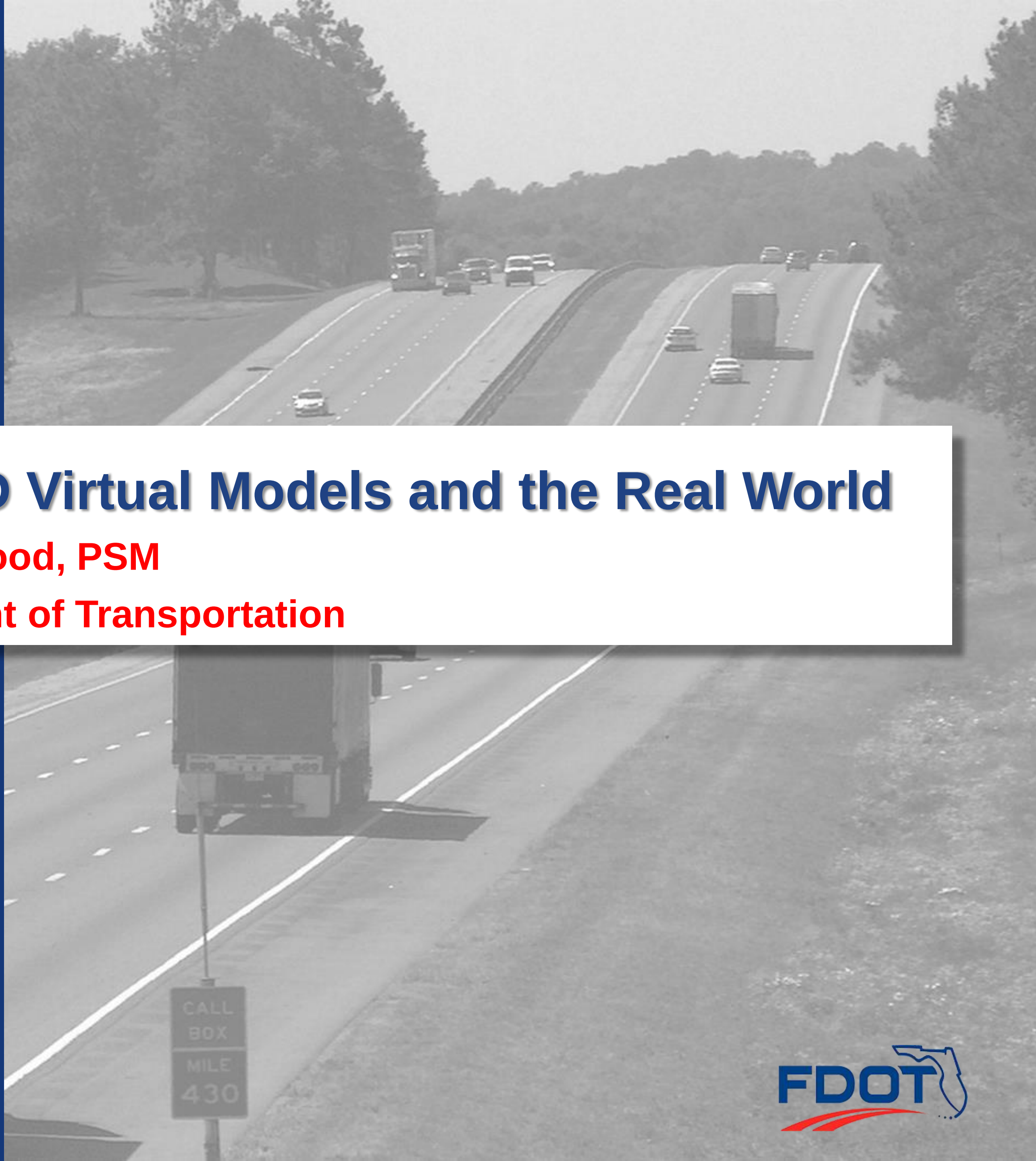
brett.wood@dot.state.fl.us
Florida Department of Transportation

David Zilkoski
davezilkoski@gmail.com
Geospatial Solutions by DBZ



Resolving Ambiguities Between 3D Virtual Models and the Real World

Brett Wood, PSM

Florida Department of Transportation

FDOT

AGENDA

- **DOT Perspective**
- **First there was BIM, then CIM, and now BIM for infrastructure**
- **NCHRP**
- **FDOT**
  - FPRN
    - How FDOT preparing for the new Datum?
  - FDOT Transportation Project Survey Control Hierarchy
    - Project Relative and Positional Accuracies
  - Open Source
    - Industry Foundation Classes – IFC
    - Geospatial databases
  - Florida Sunshine Skyway
    - Bridge Inspection and Maintenance
      - BIM

Resolving Ambiguities Between 3D Virtual Models and the Real World - DOT Perspective

- **Geodesy**
  - You can't have a virtual model of transportation infrastructure or anything geospatial without geodesy
  - Do we all have to be geodesists to use geodesy to our advantage?

- **Surveying and Mapping**
  - Bridging the gap between geodesy and geospatial
  - What about accuracy?

First there was BIM, then CIM, and now BIM for infrastructure

Building Information Modeling (BIM)

"Civil Integrated Management (CIM) is the technology-enabled collection, organization, managed accessibility, and the use of accurate data and information throughout the life cycle of a transportation asset. The concept may be used by all affected parties for a wide range of purposes, including planning, environmental assessment, surveying, construction, maintenance, asset management, and risk assessment."

-FHWA, AASHTO, ARTBA (2012)

Our goal is to make the model the basis of not only how we collaborate during design and construction of a project or corridor (Connected Site), but also how we maintain and manage the same corridor, as well as plan for future growth and changes (Life Cycle Management)

-FDOT

Building Information Modeling (BIM) for Infrastructure Building Information Modeling (BIM) is an intelligent 3D model-based approach that gives engineering and construction professionals the insight and tools to more efficiently plan, design, and build highways and bridges. The days of sharing documents with via copy plan sets and files from silo to silo through an asset's life are diminishing. With BIM, all project data from planning to decommissioning is shared electronically with ready access for all involved in the planning, building, and maintenance processes, providing more efficient data exchange.

FHWA

NCHRP 08-174 [RFP]

- Development of a Surveying and Mapping Guide for Transportation Projects
- Posted Date: 9/6/2023
- BACKGROUND
- Many state and federal transportation agencies have their own surveying and mapping standards, which leads to inconsistencies in measurements used in the design and construction of transportation assets. A national surveying and mapping standard would ensure spatial consistency, improve efficiency, minimize errors, and reduce duplication efforts.
- OBJECTIVE
- The objective of this research is to create a surveying and mapping guide for identifying positional accuracies of geospatial data used in transportation projects by state agencies and others that clearly specifies practices consistent with open data standards, the NSRS, and the deprecation of the U.S. survey foot.
- The guide will help agencies establish an appropriate level of accuracy for a given application and provide the details of practices that, if widely adopted, could ensure geospatial data are reliably and efficiently captured, shared, and reused.

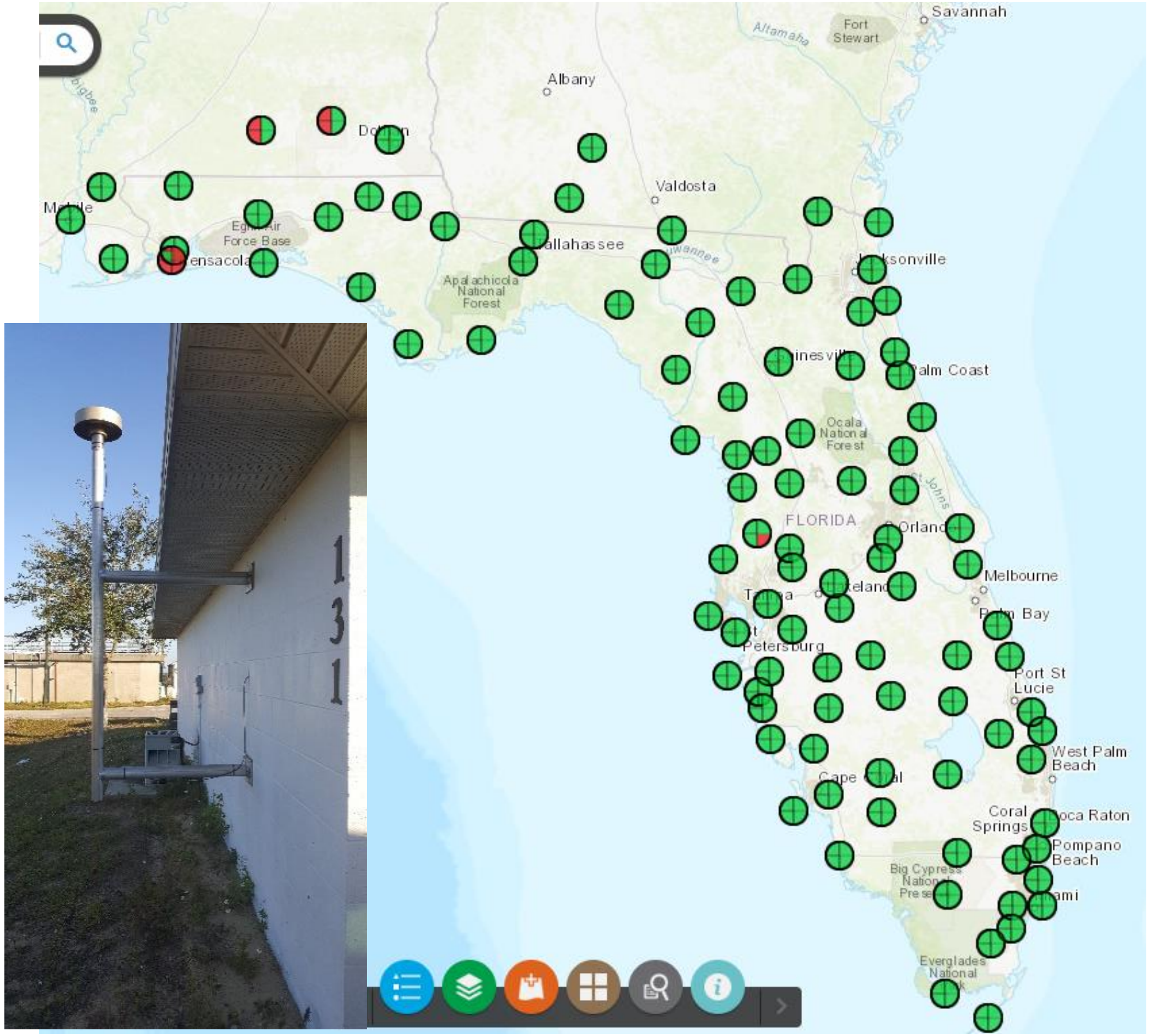
Florida Permanent Reference Network (FPRN)

- FPRN is a physical asset of approximately 100 continuously operating reference stations (CORS) throughout Florida maintained by FDOT.

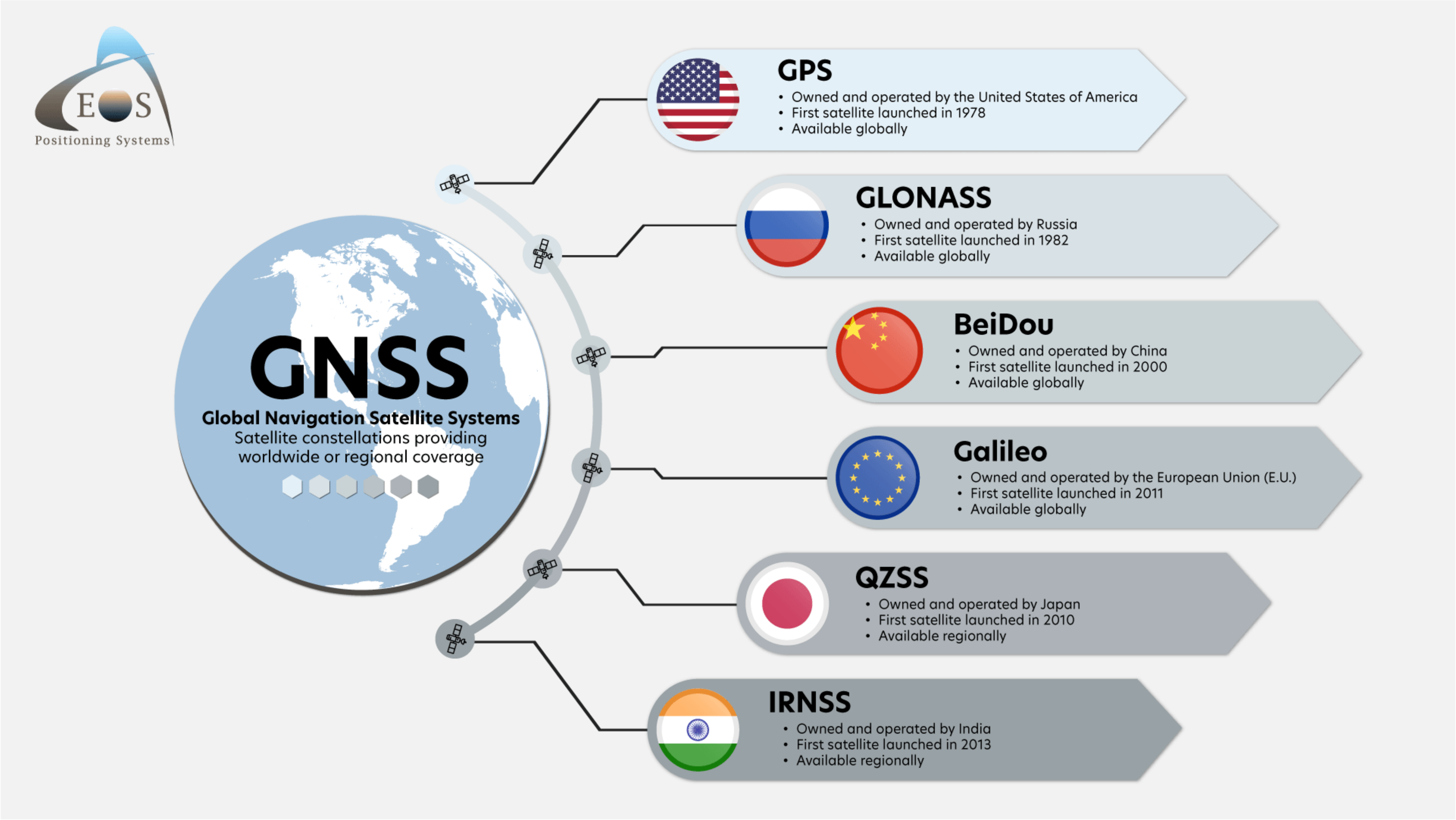
- The FPRN receives radio signals containing positioning information from the Global Navigation Satellite System (GNSS) to provide up to centimeter level geospatial positioning corrections to users.

- The FPRN is the geodetic foundation supporting geospatial activities throughout FDOT, including land surveying, engineering, construction, emergency management, and infrastructure maintenance.

https://www.fdot.gov/geospatial/fprn.shtm

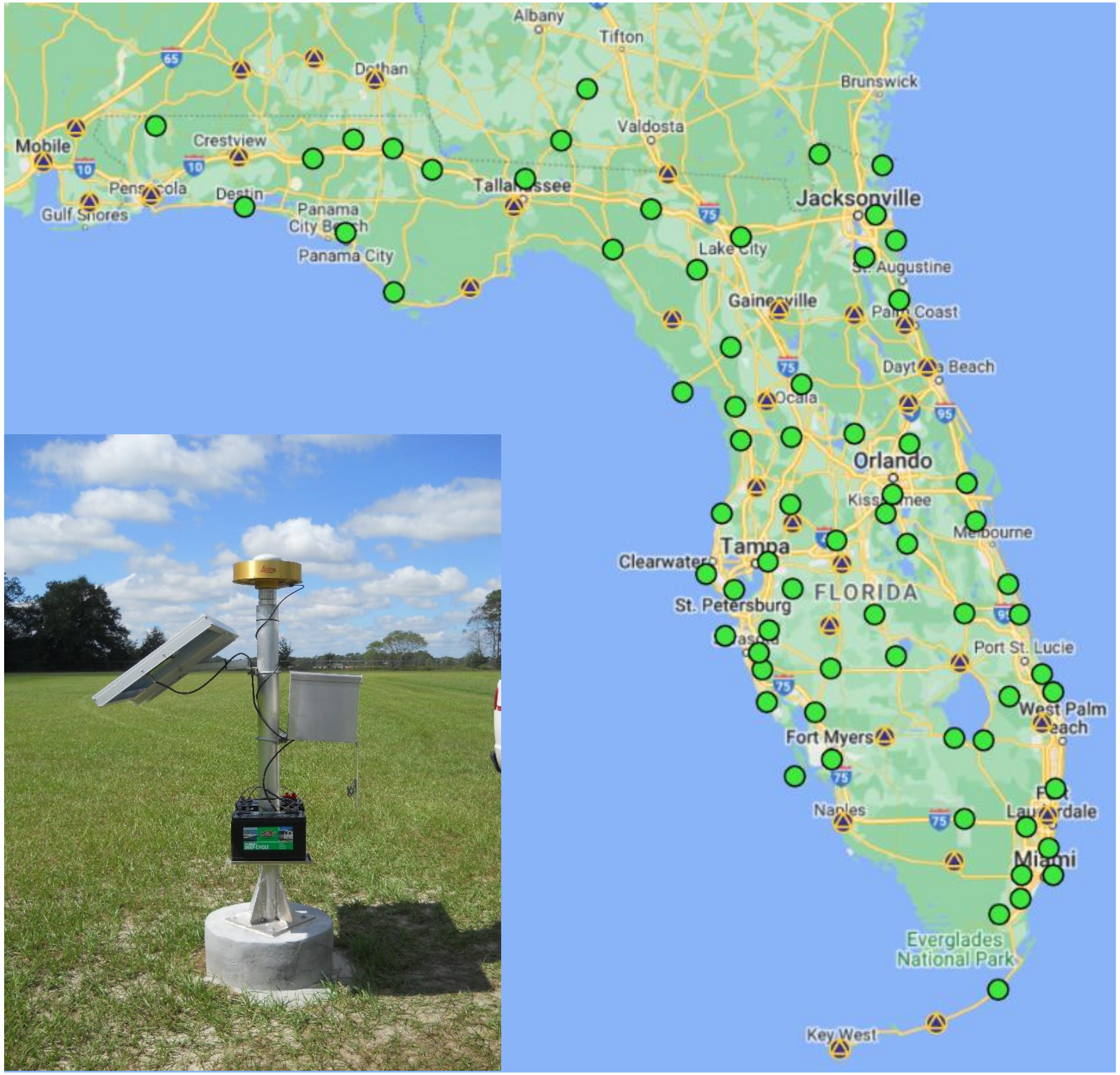


Global Navigation Satellite Systems (GNSS)



Preparing for the new NGS Datum

- FPRN Alignment with NGS CORS
  - FDOT submitted FPRN base station data through OPUS Projects and working with NGS so that approximately 63 additional FPRN stations are included in the NGS Integrated Database, and thus utilized when producing OPUS solutions for users.
  - This will afford better alignment of our network with the NSRS as we approach the publication of a new national datum by NGS, thus resulting in greater geospatial confidence, and continued deliverance of foundational geodetic positioning and data governance for all department and work program surveying and mapping products and services.

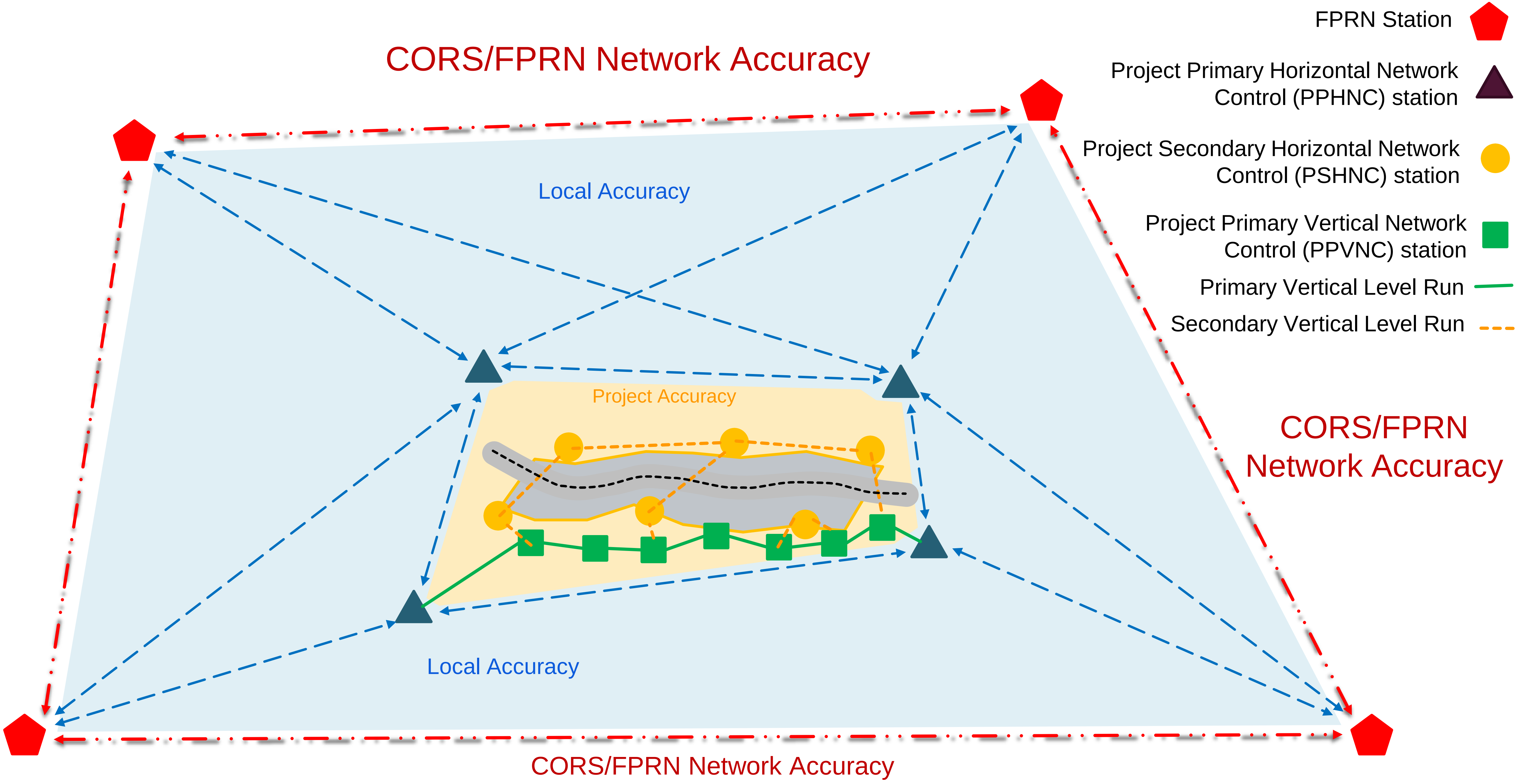


Who uses the FPRN ?

- **Shortlist of Benefits**
  - Reduces the number of survey staff in the field.
  - Provides a common geospatial framework that relates projects and assets together and allows for continuous monitoring of infrastructure.
  - Accurate positioning during emergency response.

Total Number of Accounts 6,038	**Total Number of Users 10,572**	**Total Number of Connections 11.5 Million (2015-2023)**
Total Connection Hours 15 Million (2015-2023)	**Total FDOT Hours 1,853,300**	**University with the most users University of Florida Go Gators**

FDOT Transportation Project Survey Control Hierarchy



FDOT Surveying & Mapping Handbook – Appendix C

https://www.fdot.gov/Geospatial/doc-pubs.shtm

FPRN Accuracies (Network Accuracies)

Control Type	Purpose	Method	Horizontal Positional Accuracy	Relative Horizontal Accuracy	Vertical Positional Accuracy	Relative Vertical Accuracy	Recommended Minimum Spacing
FPRN	Statewide Geodetic basis for all geospatial measurements	Continuous GNSS observations	1 cm	N/A	3 cm	N/A	N/A

Project Primary Control (PPC) Accuracies (Local Accuracies)

Control Type	Purpose	Method	Horizontal Positional Accuracy	Relative Horizontal Accuracy	Vertical Positional Accuracy	Relative Vertical Accuracy	Recommended Minimum Spacing
Project Primary Control (PPC)	Local geodetic horizontal and vertical control - basis for all project survey measurements	Static GNSS observations	1 cm ~ 0.033'	10 ppm	0.01 m ~ 0.033'	9 mm x √ (kilometers)	800 m ~ 2600'

Project Secondary Control (PSC) Accuracies (Local Accuracies)

Control Type	Purpose	Method	Horizontal Positional Accuracy	Relative Horizontal Accuracy	Vertical Positional Accuracy	Relative Vertical Accuracy	Recommended Minimum Spacing
Project Secondary Control (PSC)	Local geodetic horizontal and vertical control - basis for all project survey measurements	*GNSS or terrestrial observations	2 cm ~ 0.066’	50 ppm	0.02 m ~ 0.066’	12 mm x √ (kilometers)	150 m ~ 500’

Industry Foundation Classes - IFC

At its core, buildingSMART enables the entire built asset industry to improve the sharing of information throughout the lifecycle of project or asset. By breaking down the silos of information, end users can better collaborate and cooperate regardless of which software application they are using. buildingSMART's technical core is based around Industry Foundation Classes (IFC) which was ISO certified in 2013.

IFC is a standardized, digital description of the built asset industry. It is an open, international standard (ISO 16739-1:2018) and promotes vendor-neutral, or agnostic, and usable capabilities across a wide range of hardware devices, software platforms, and interfaces for many different use cases.

- **Open format; vendor – neutral**
- **Object-Oriented**
  - Schema elements inherit from base classes
- **Adopted by AASHTO in 2019 as the Standard Data Schema for the Exchange of Electronic Engineering Data**
- **Schema version 4.3 – International Standard with ISO**

Expanding IFC

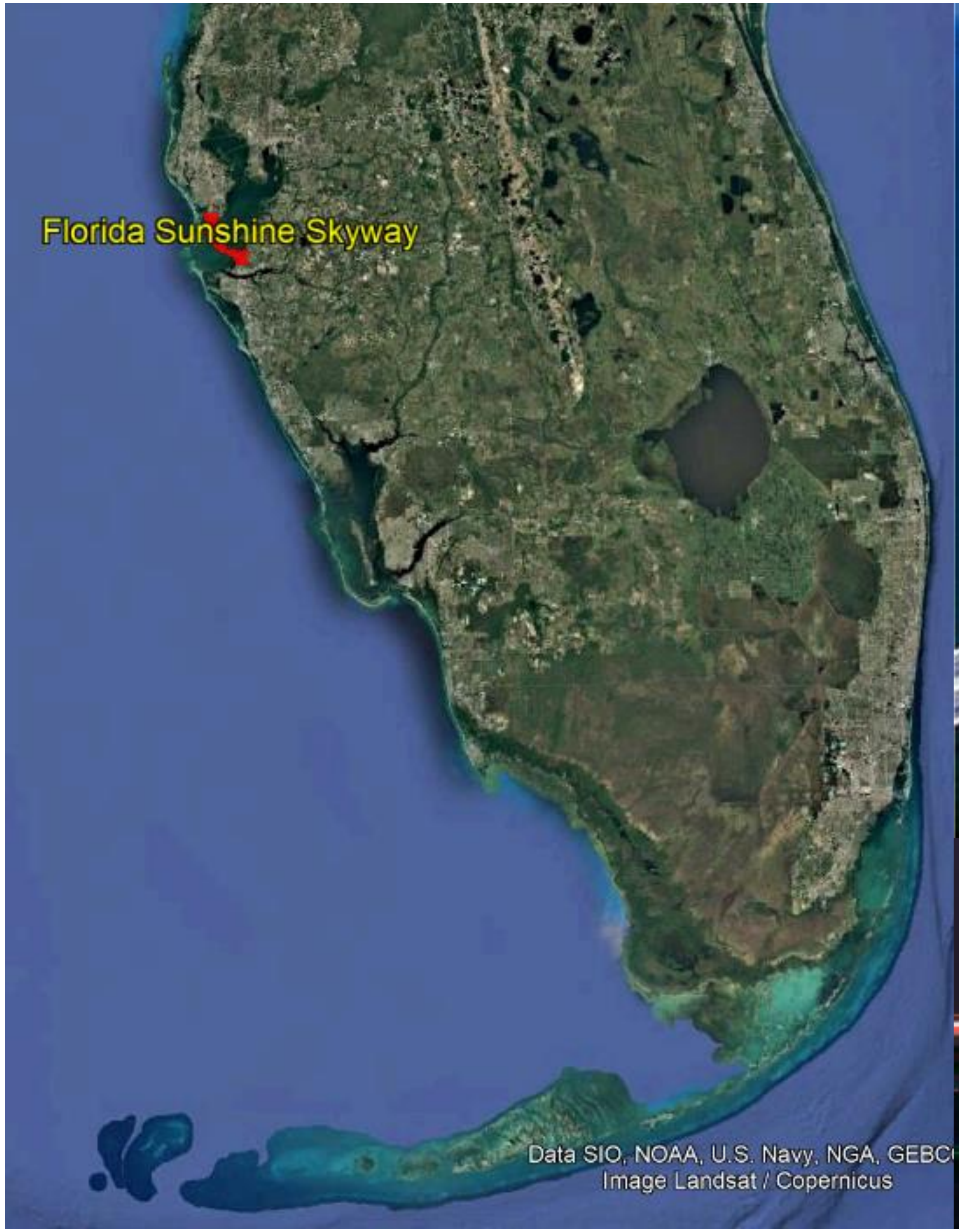
- **Level of Georeferencing (LoGeoRef) using IFC for BIM**
  - Clemen Christian and Görne Hendrik
  - Received: September 2018 / Accepted: October 2018 / Published: March 2019 © Journal of Geodesy, Cartography and Cadastre/ UGR
    - Using the Industry Foundation Classes (IFC) to georeference building models (BIM) we propose a “pessimistic assumption”, because Building Models in IFC are often not perfectly or sometimes not at all georeferenced, in practice. For this reason, our approach defines a “metric” using standard conform IFC Entities (buildingSmart, ISO 16739:2013) only. The higher the proposed Level of Georeferencing (LoGeoRef) is, the more quality of georeferencing is specified. Each level comprises their own IFC-schema attributes and is standing on its own. The metric is implemented in a free software tool for checking and editing geo-transformation in IFC files.

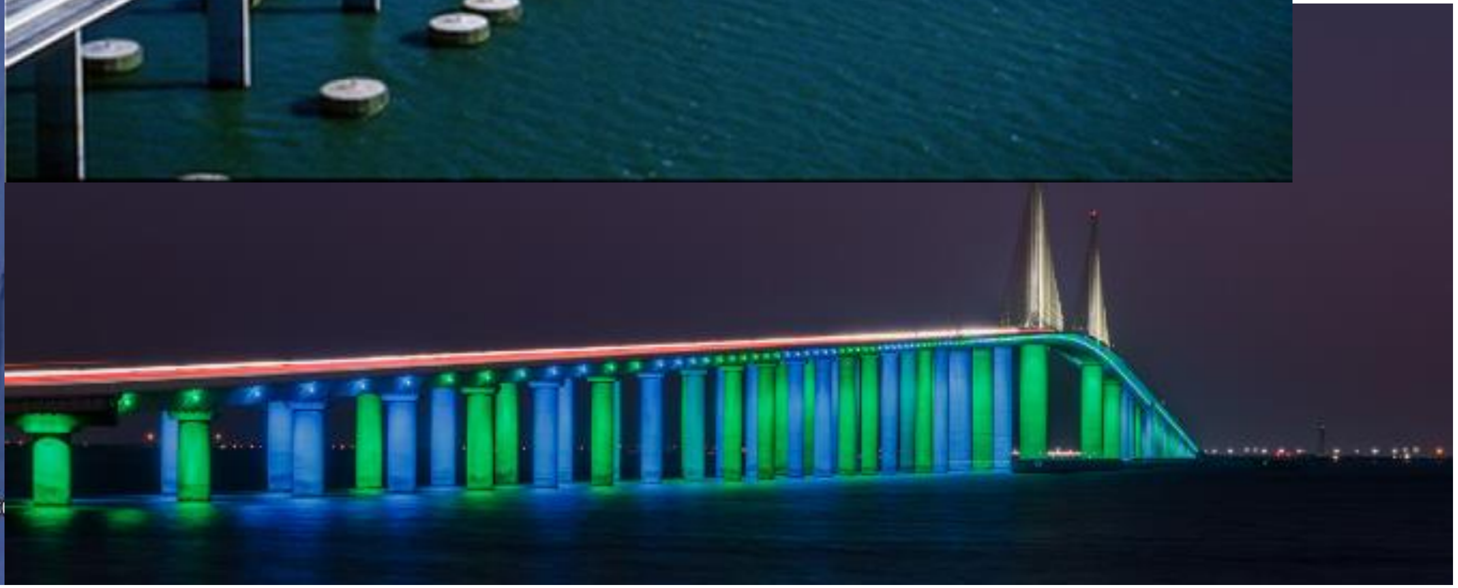
https://jgcc.geoprevi.ro/docs/2019/10/jgcc_2019_no10_3.pdf

Open Source

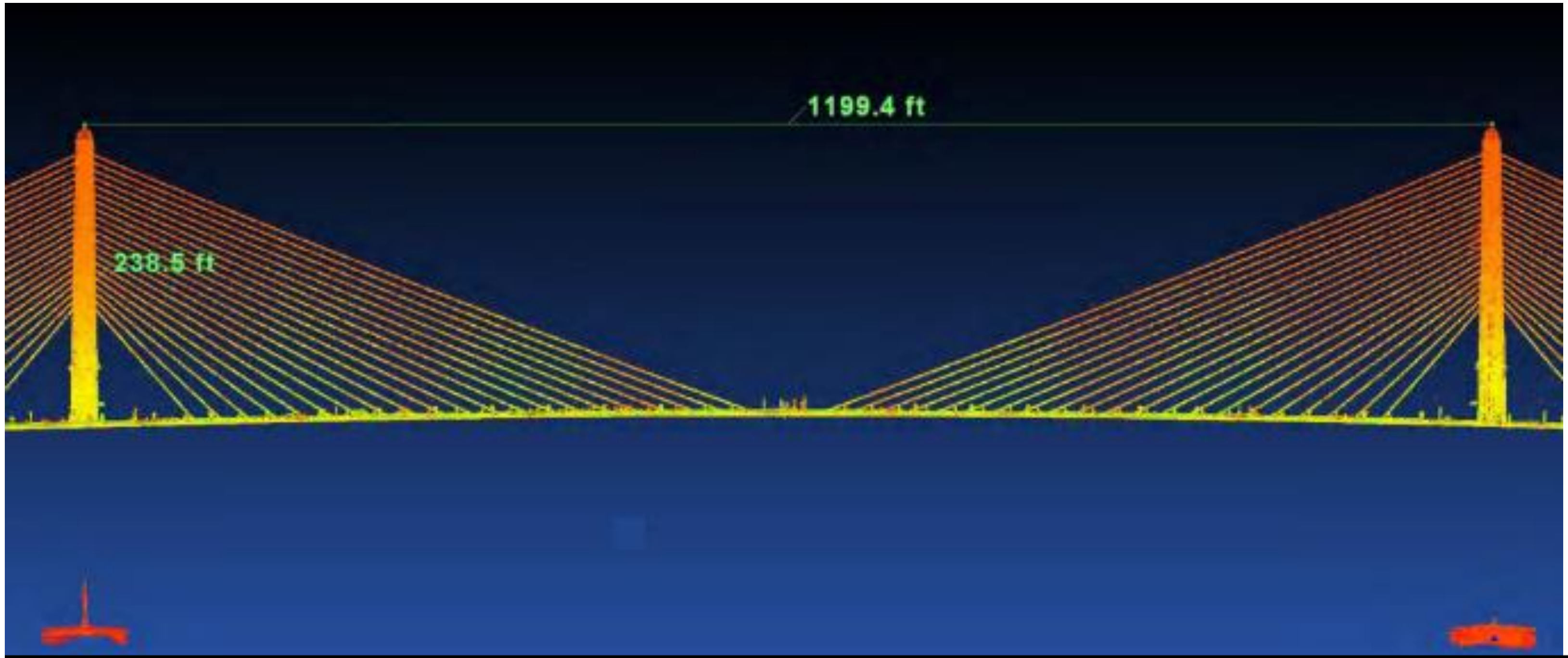
General Information	PostgreSQL/PostGIS	Oracle Spatial	SQL Server	Snowflake	neo4j
License	PostgreSQL License GNU General Public License	Commercial	Commercial	Commercial	Open-Source Community Edition Commercial Edition
Cost	Free (Both)	Commercial via FDOT ELA	Commercial via FDOT ELA	Priced by Usage	Free (Community Edition) Commercial Edition
Release Year	1986 (PostgreSQL) 2001 (PostGIS)	1979	April 24, 1989	October, 2014	February 2010 (v1.0)
Current Release	PostgreSQL v15.2 (February 2023) PostGIS v3.3.2 (April 2023)	21c (January 2021)	SQL Server 2022 (November 16,2022)	N/A	v5.6 (March 2023)
Paid Enterprise Support	✓	✓	✓	✓	✓
OIT Support	✗	½	✓	½	✗
RDF/Graph Data Model Support	Apache AGE	Oracle Graph	SQL Graph	✗	✓
Geospatial Support					
Vector Data	✓	✓	✓	✓	✗
Geometry	✓	✓	✓	✓	Point Geometries Only
Geometry Functions	250+				3
Geography	✓	✓	✓	✓	Point Geographies Only
Geography Functions	31				3
Vector 3D & 4D	✓	✓	✓	✓	
3DM Support	✓	✓	Read/Write Only	✓	✗
3DZ Support	✓	✓	Read/Write Only	✗	Point Geographies/Geometries Only
4DZM Support	✓	✓	Read/Write Only	✗	✗
Topology & Network Data	✓	✓	✗	✗	✓
Coordinate Systems	✓	✓	✗	✗	✗
Custom Coordinate Systems	✓	✓	✗	✗	✗
Projections/Transformations	✓	✓	✗	✗	✗
Custom	✓	✓	✗	✗	✗
Raster Data	✓	✓	✗	✗	✗
Raster Functions	288	✓	✗	✗	✗
Supported Raster Formats	146 filetypes (via GDAL)	✓	BLOB Only	✗	✗
Lidar Point Cloud	✓	✓	✗ BLOB Only	✗	✗
Extract-Transform-Load					
Native Spatial ETL Tools	✓	✓	✓	✓	✗

Florida Sunshine Skyway – Bridge Inspection and Maintenance





Florida Sunshine Skyway - BIM Project



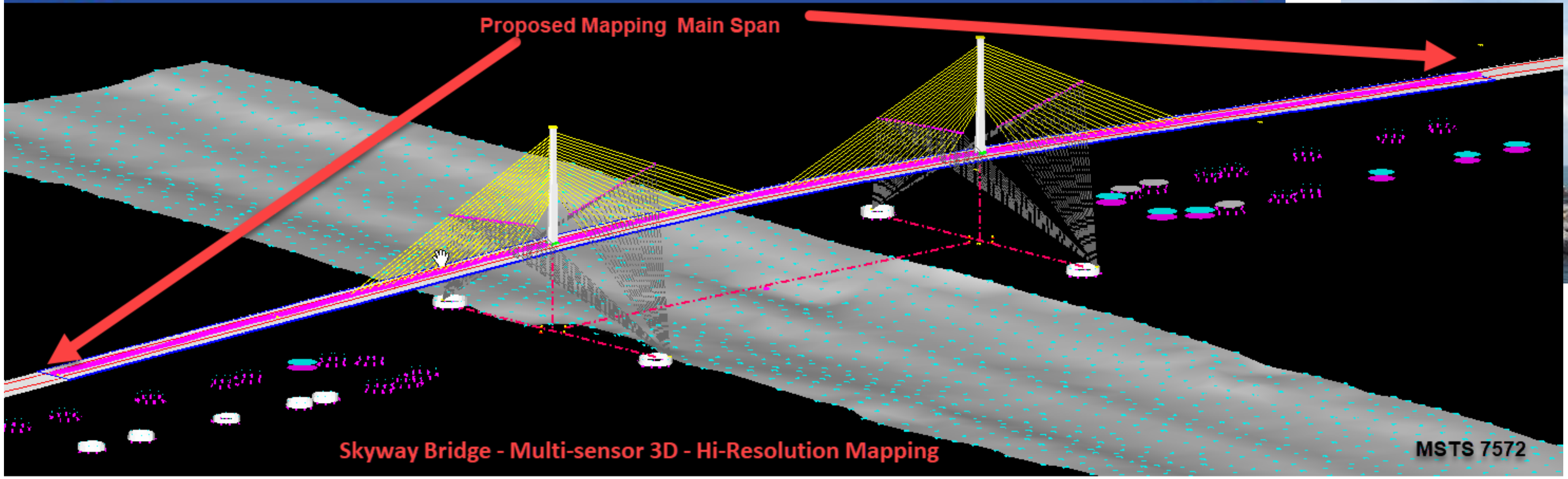
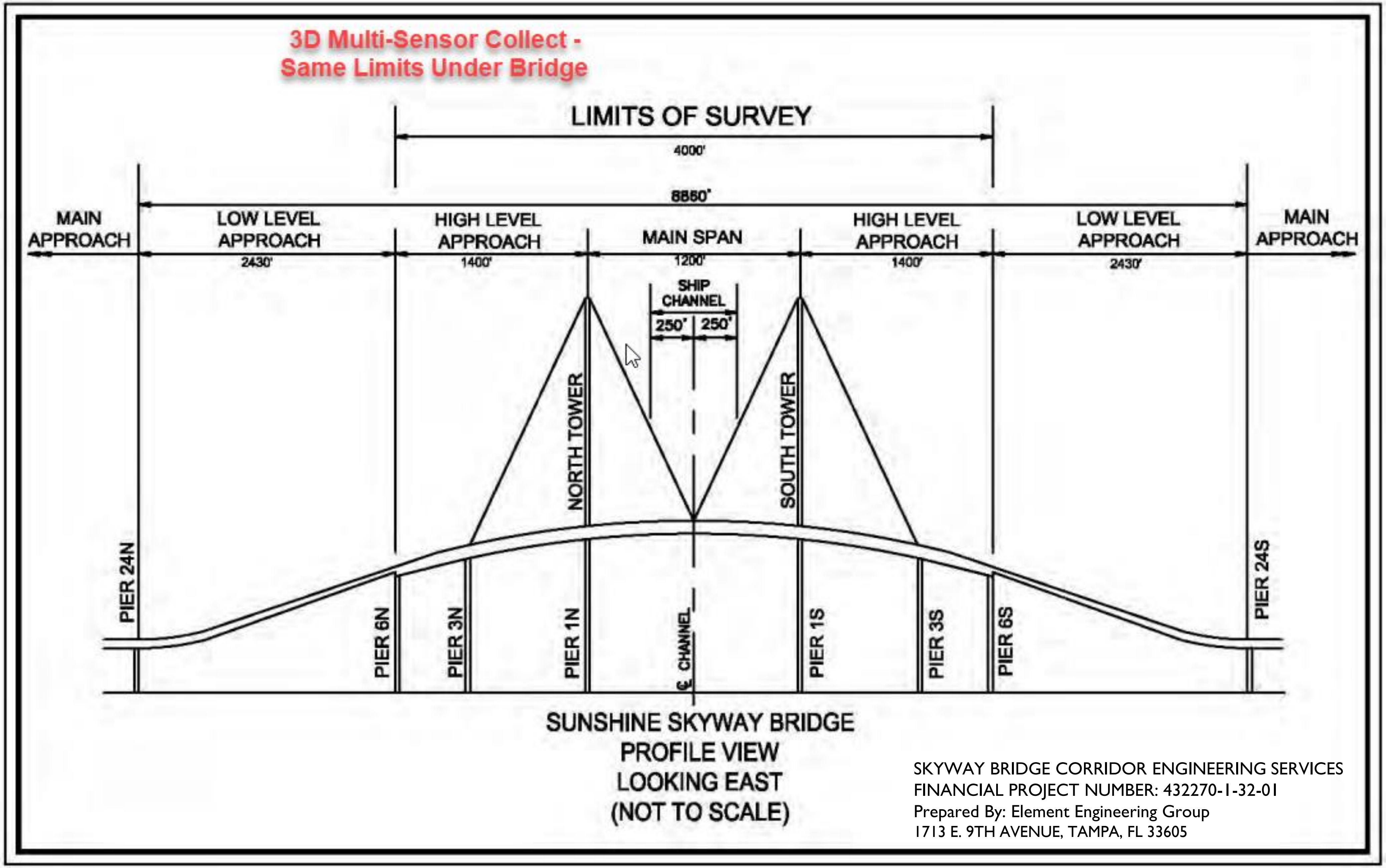


Exhibit B


3D Multi-Sensor Collect - Same Limits Under Bridge
LIMITS OF SURVEY
4000'
8860'
MAIN APPROACH
LOW LEVEL APPROACH
2430'
HIGH LEVEL APPROACH
1400'
MAIN SPAN
1200'
SHIP CHANNEL
250'
250'
HIGH LEVEL APPROACH
1400'
LOW LEVEL APPROACH
2430'
MAIN APPROACH
NORTH TOWER
SOUTH TOWER
PIER 24N
PIER 6N
PIER 3N
PIER 1N
℄ CHANNEL
PIER 1S
PIER 3S
PIER 6S
PIER 24S
SUNSHINE SKYWAY BRIDGE
PROFILE VIEW
LOOKING EAST
(NOT TO SCALE)
SKYWAY BRIDGE CORRIDOR ENGINEERING SERVICES
FINANCIAL PROJECT NUMBER: 432270-1-32-01
Prepared By: Element Engineering Group
1713 E. 9TH AVENUE, TAMPA, FL 33605

Florida Sunshine Skyway

Aerial Photogrammetric Imagery for Measuring Bridge Monitoring Points and Cable Stays

Proposed Pixel Size in the capture of RGBN bands using Photogrammetric Cameras. To adequately model surfaces and perform sub-pixel target measurement Photogrammetric/Computer Vision Algorithms will be used.

Maintenance of Bridge Stay Cable Systems Copyright National Academy of Sciences. All rights reserved. photogrammetric algorithms, “sub-pixel target measurements” are obtained and transformed into three-dimensional coordinates.

Photogrammetric techniques can also be used for static measurements such as cable sag

Inspection and Maintenance of Bridge_NAP13689

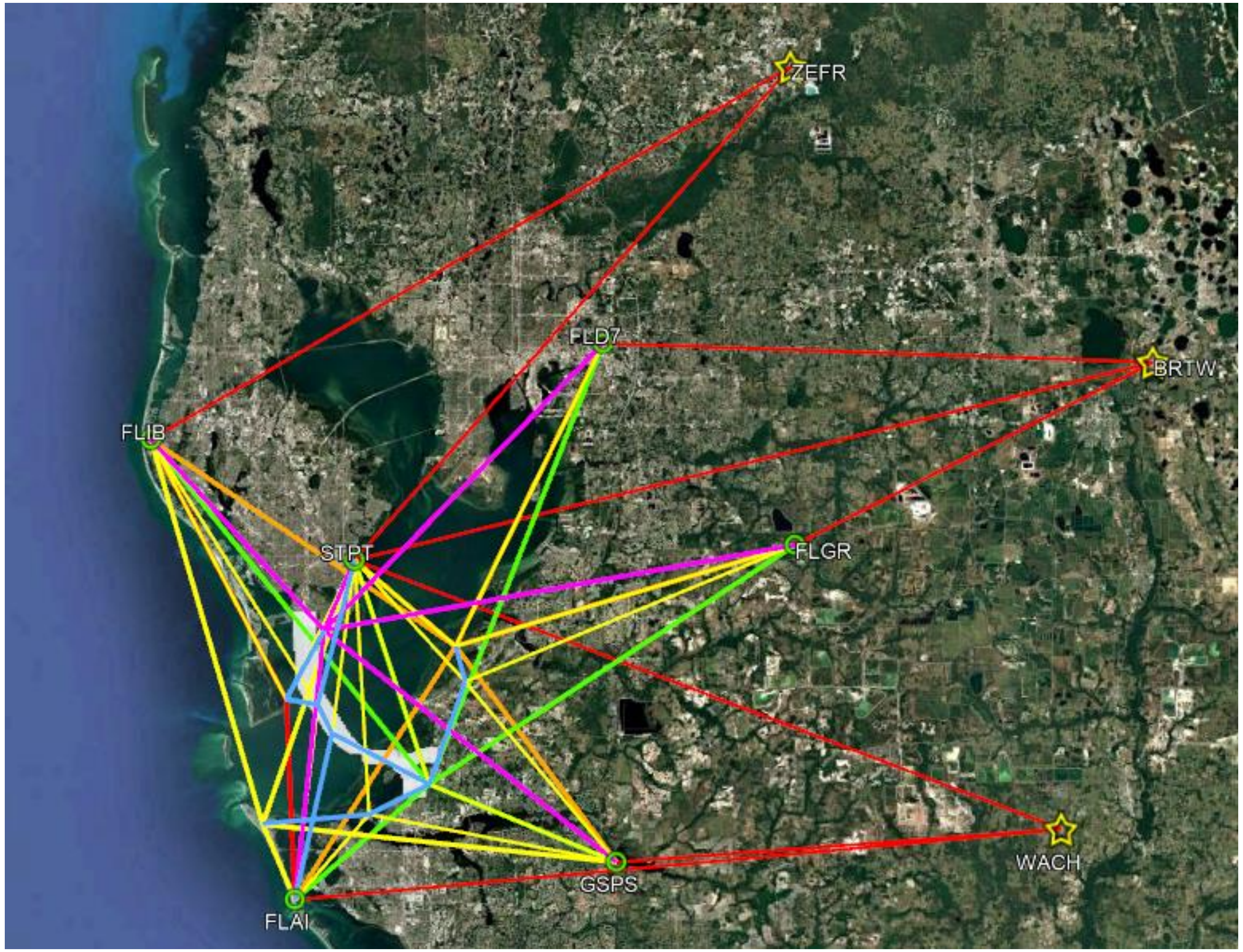
Monument Diameter 9 cm

3 cm GSD (Ground Sample Distance)

Florida Sunshine Skyway

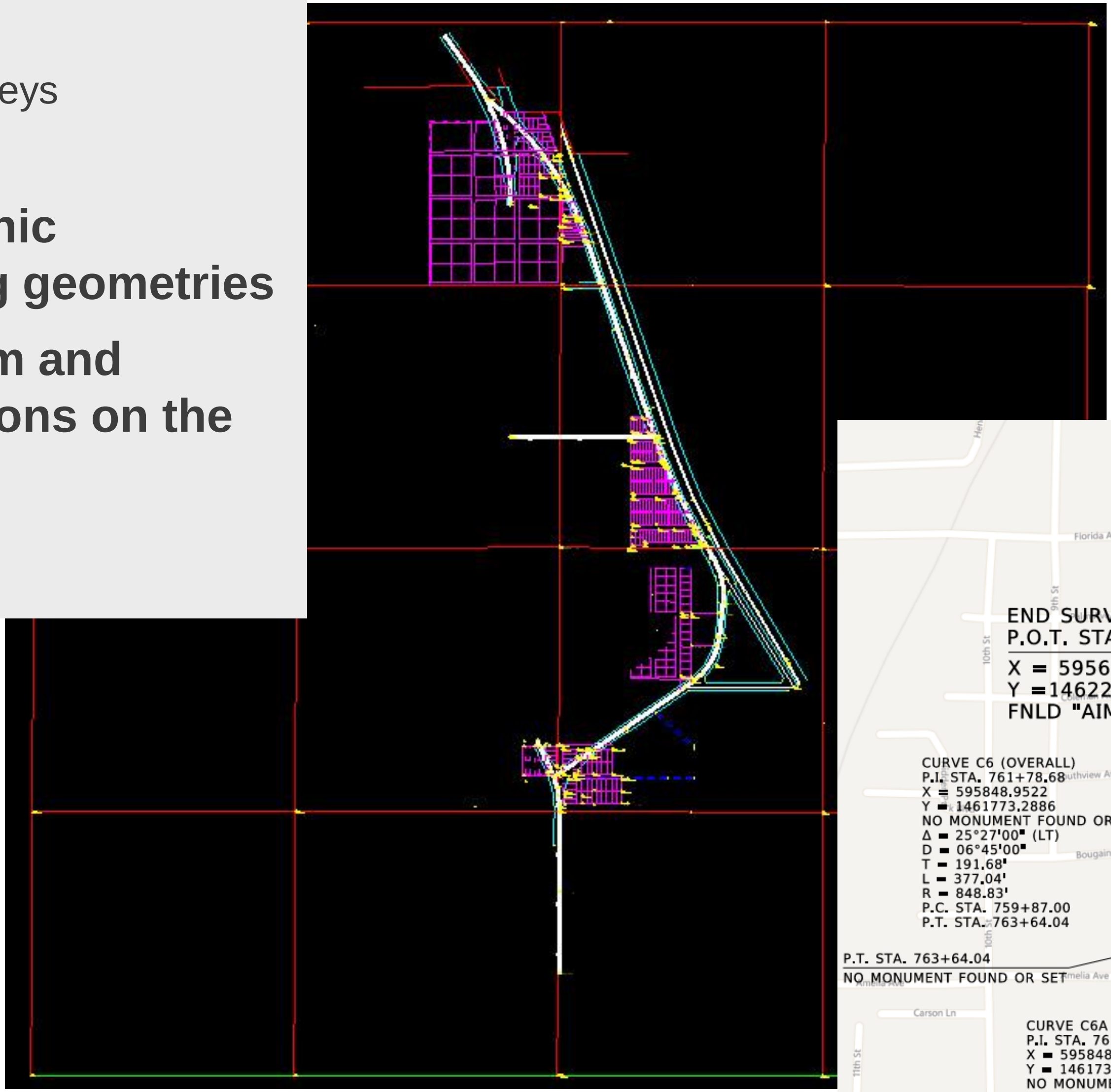
Project Limits

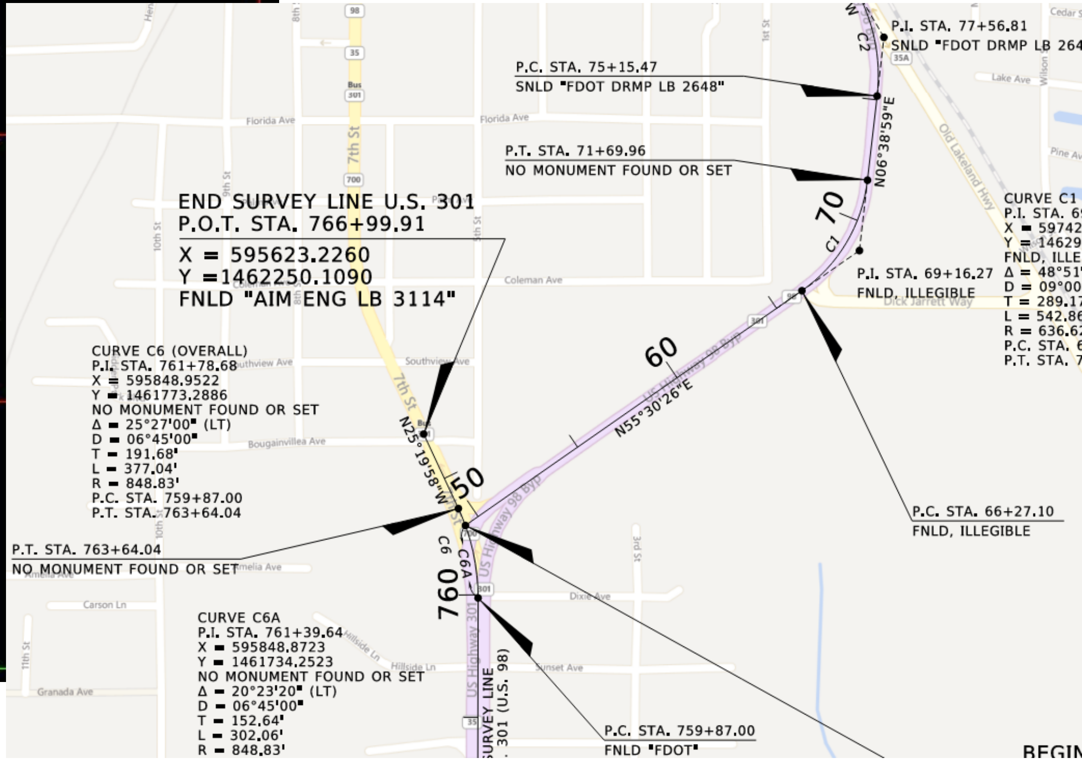
Project Primary Control Network Accepted by NGS



Future Statewide Survey Alignment

- **A statewide digital survey/corridor alignment**
  - Built from R/W Control Surveys
  - Not sheets
- **Controlled by Geographic Coordinates controlling geometries**
- **Ability to perform datum and projection transformations on the fly**

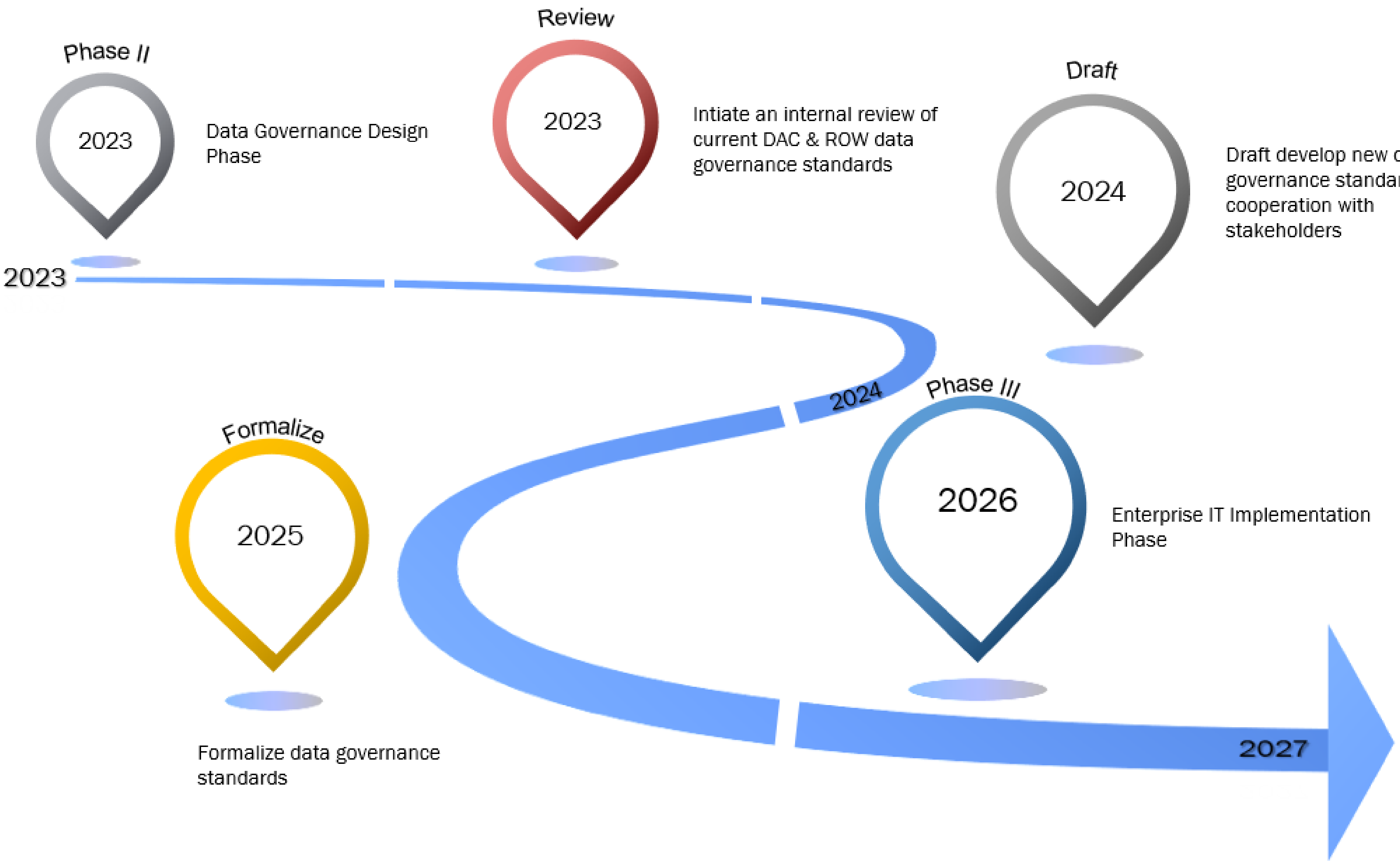




Next Steps & Future Directions

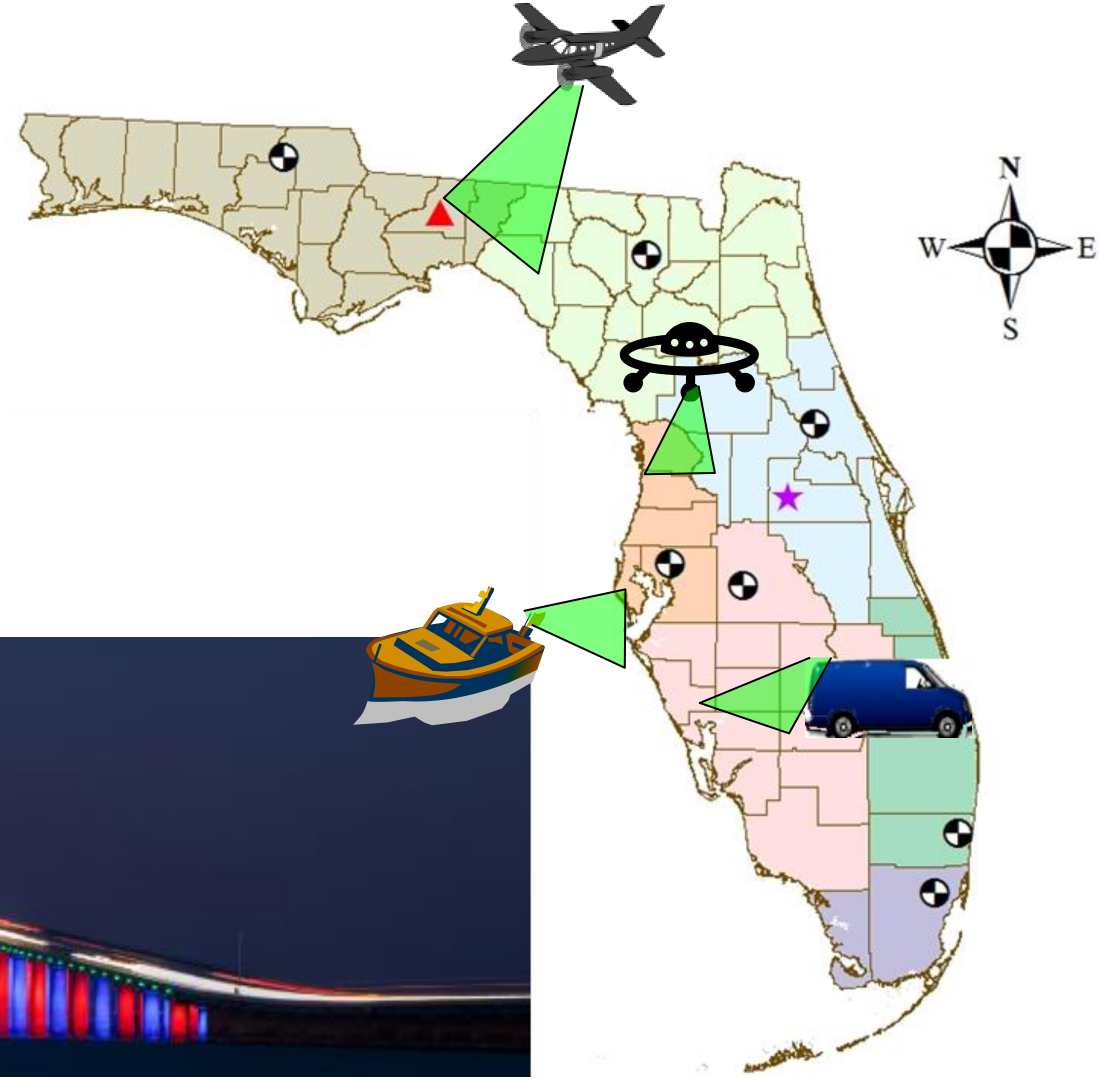
- CSMO internal review of current data governance standards for control data
- Develop new data governance standards in cooperation with districts and other stakeholders
- Working in cooperation with leadership & OIT, license & deploy FME Flow (Server) as an approved enterprise resource
- Working in cooperation with leadership & OIT, select and deploy an enterprise database platform

Next Steps & Future Directions



Resolving Ambiguities Between 3D Virtual Models and the Real World

"Change is inevitable, misery is optional" **- Dr. Tom, FDOT Leadership Academy**



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Resolving Ambiguities Between 3D Virtual Models and the Real World

Ron Gant

Infotech

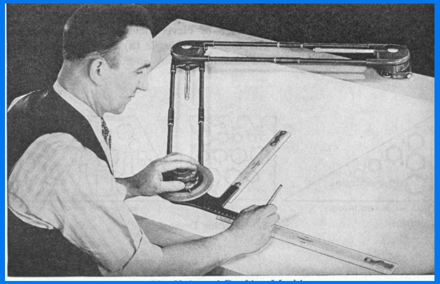
Hardware

- "I think there is a world market for maybe five computers."

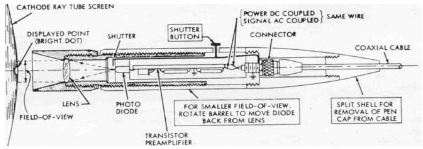
  Thomas Watson, president of IBM, 1943

Early constraints

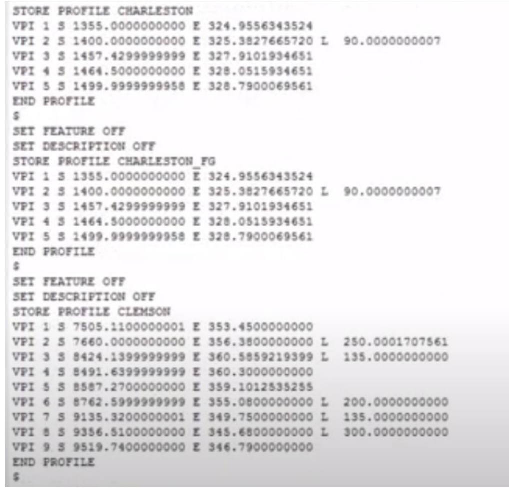
The Beginning of CAD/CADD



- 1963, Dr Ivan Sutherland
- MIT – CAD research



- Mid 1960's, Professor Charles L. Miller (MIT)
  - Terrain models
  - COGO



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STORE PROFILE CHARLESTON
VPI 1 S 1355.0000000000 E 324.9556343524
VPI 2 S 1400.0000000000 E 325.3827665720 L  90.0000000007
VPI 3 S 1457.4299999999 E 327.9101934651
VPI 4 S 1464.5000000000 E 328.0515934651
VPI 5 S 1499.9999999958 E 328.7900069561
END PROFILE
$
SET FEATURE OFF
SET DESCRIPTION OFF
STORE PROFILE CHARLESTON_FG
VPI 1 S 1355.0000000000 E 324.9556343524
VPI 2 S 1400.0000000000 E 325.3827665720 L  90.0000000007
VPI 3 S 1457.4299999999 E 327.9101934651
VPI 4 S 1464.5000000000 E 328.0515934651
VPI 5 S 1499.9999999958 E 328.7900069561
END PROFILE
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SET FEATURE OFF
SET DESCRIPTION OFF
STORE PROFILE CLEMSON
VPI 1 S 7505.1100000001 E 353.4500000000
VPI 2 S 7660.0000000000 E 356.3800000000 L  250.0001707561
VPI 3 S 8424.1399999999 E 360.5859219399 L  135.0000000000
VPI 4 S 8491.6399999999 E 360.3000000000
VPI 5 S 8587.2700000000 E 359.1012535255
VPI 6 S 8762.5999999999 E 355.0800000000 L  200.0000000000
VPI 7 S 9135.3200000001 E 349.7500000000 L  135.0000000000
VPI 8 S 9356.5100000000 E 345.6800000000 L  300.0000000000
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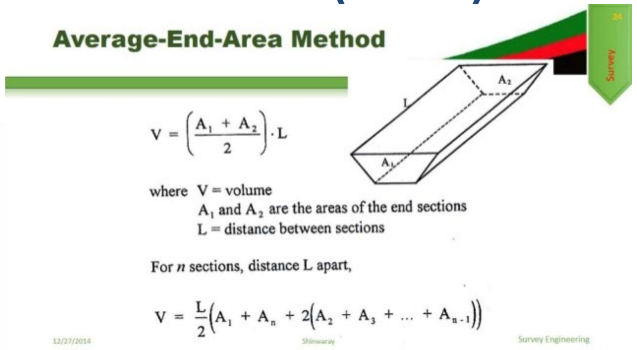


Part 1

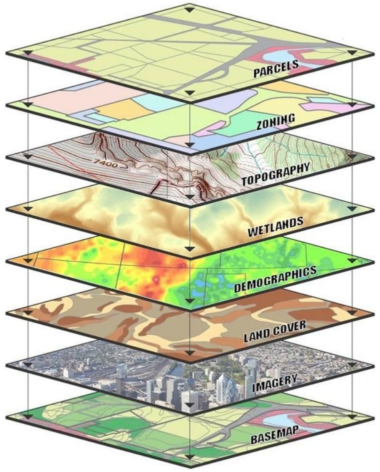
The Digital Transformation

infotech

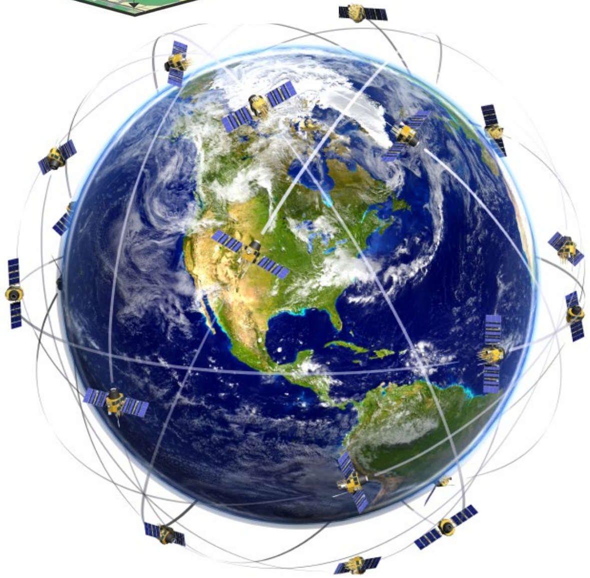

WAYMO

Technology

+ GIS



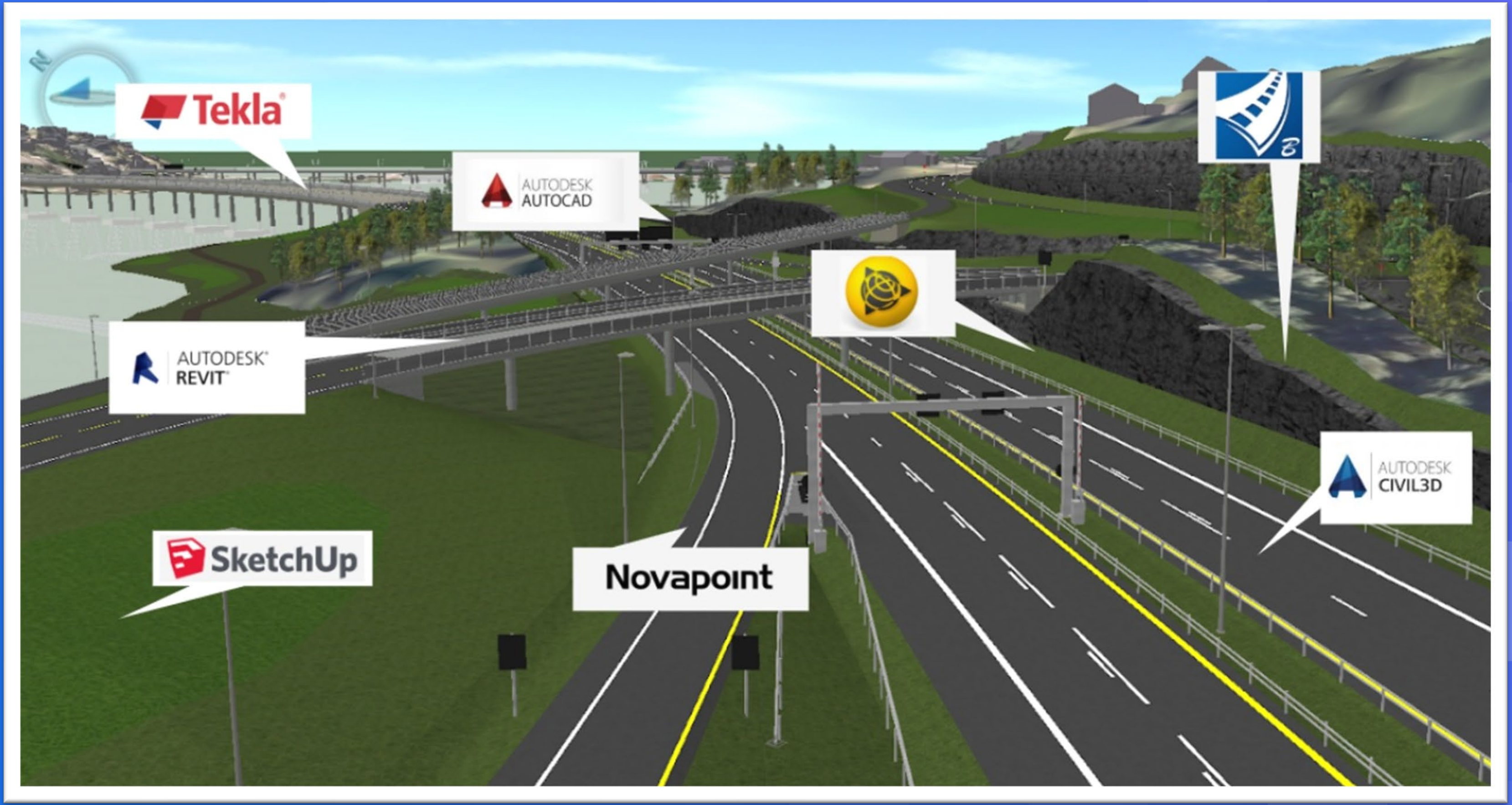
+ GPS



Flat Earth Society?

The Connected Environment

No
Vendor Is
an Island



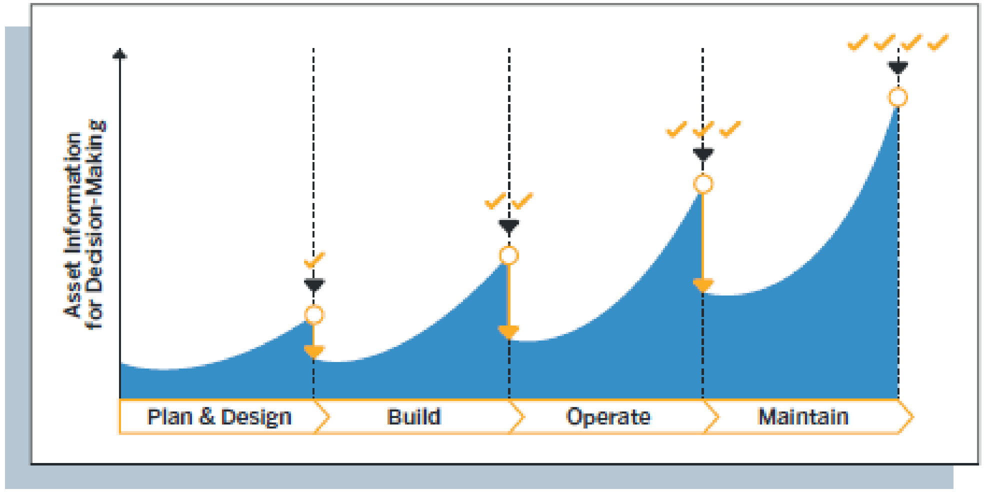
Quadri – Trimble, Inc.

infotech

Data Connectivity

Data Loss Causes Productivity Setbacks

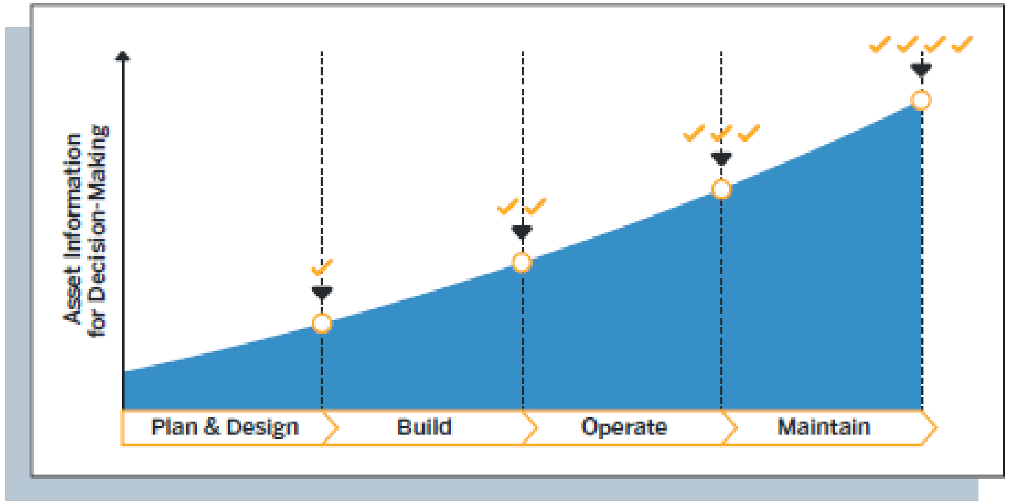
Lack of Decision-Making Support



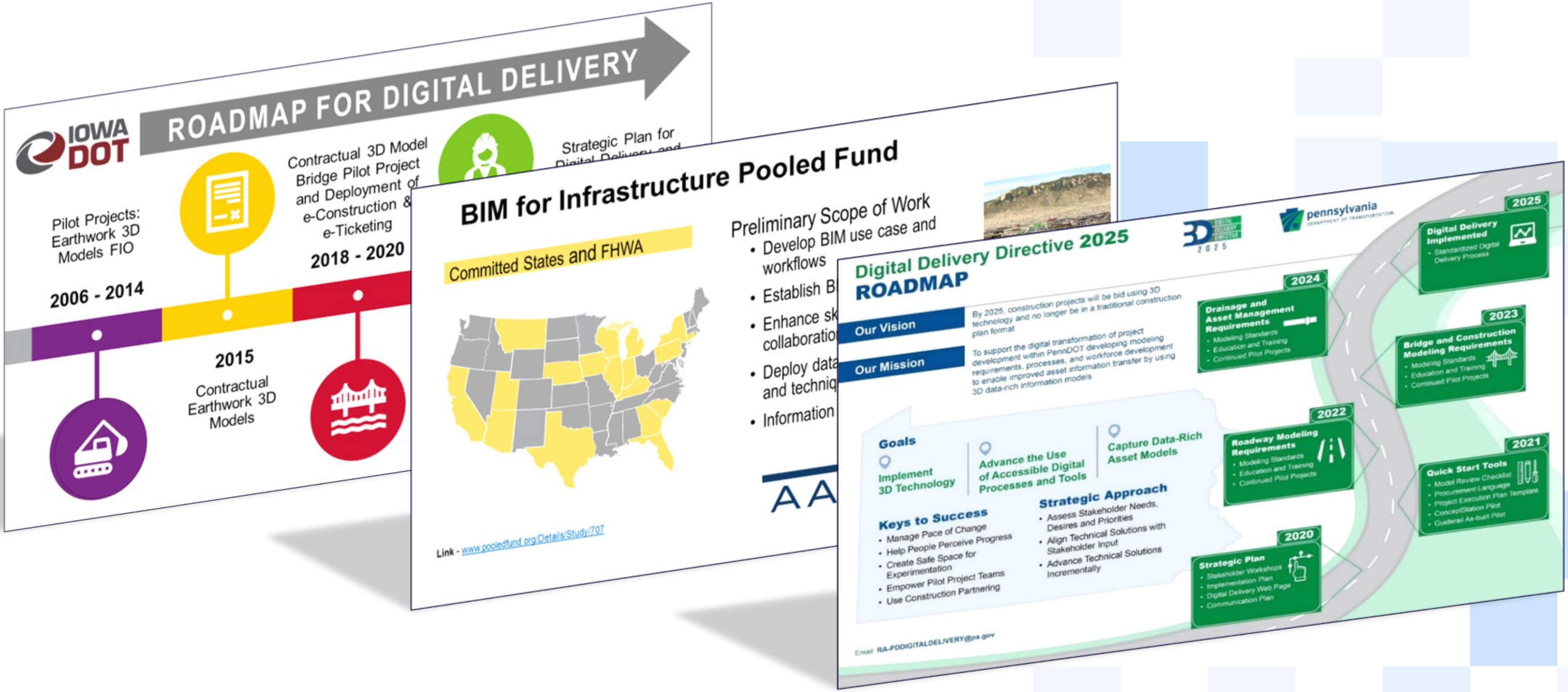
This data loss—and the resulting lack of decision-making support—dampens productivity, driving up capital expenditures by an estimated 5%-8% and operational costs by as much as 15%[3].

Connected Data Improves Productivity

Informed Decision-Making Across the Lifecycle

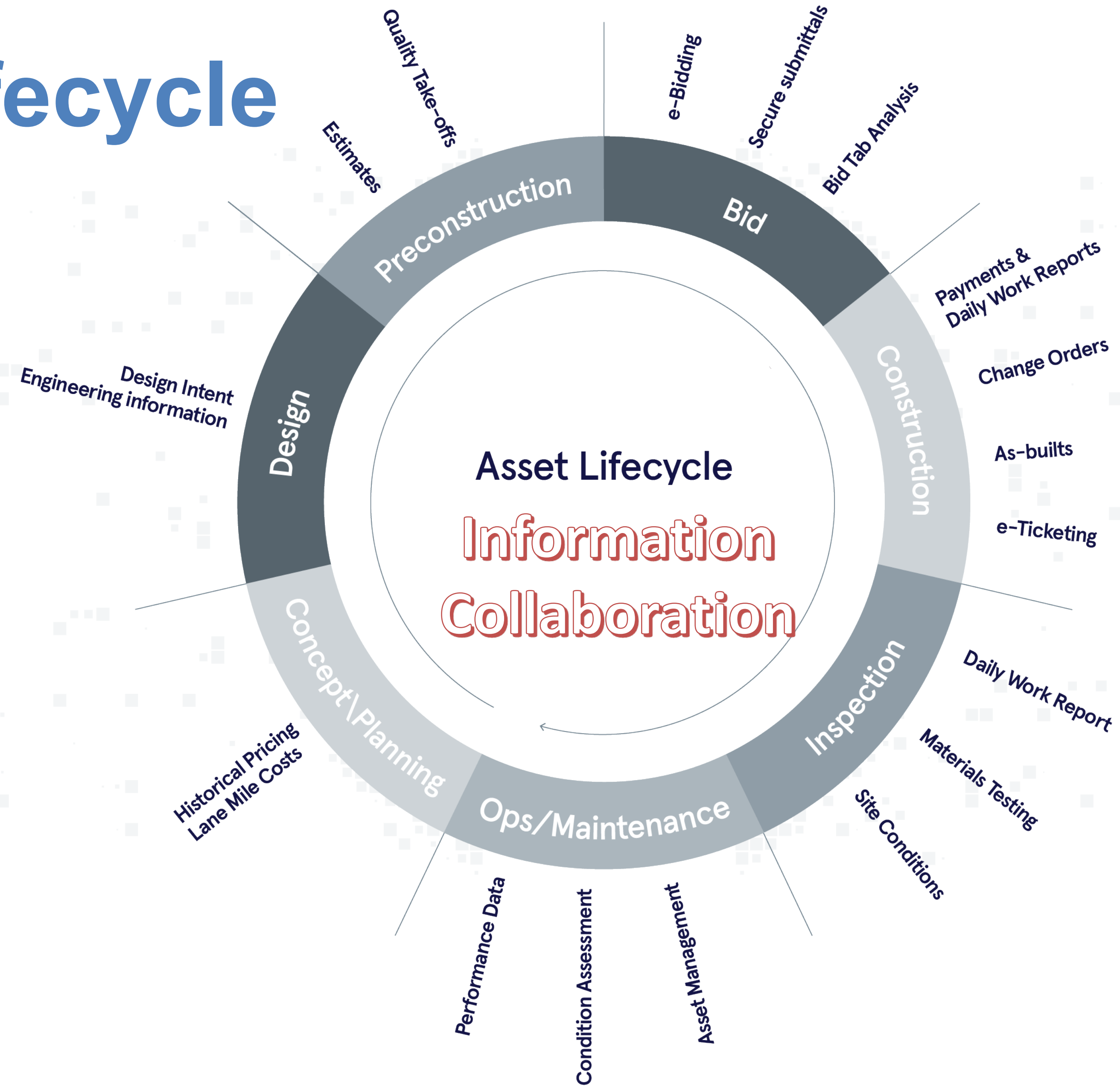


infotech

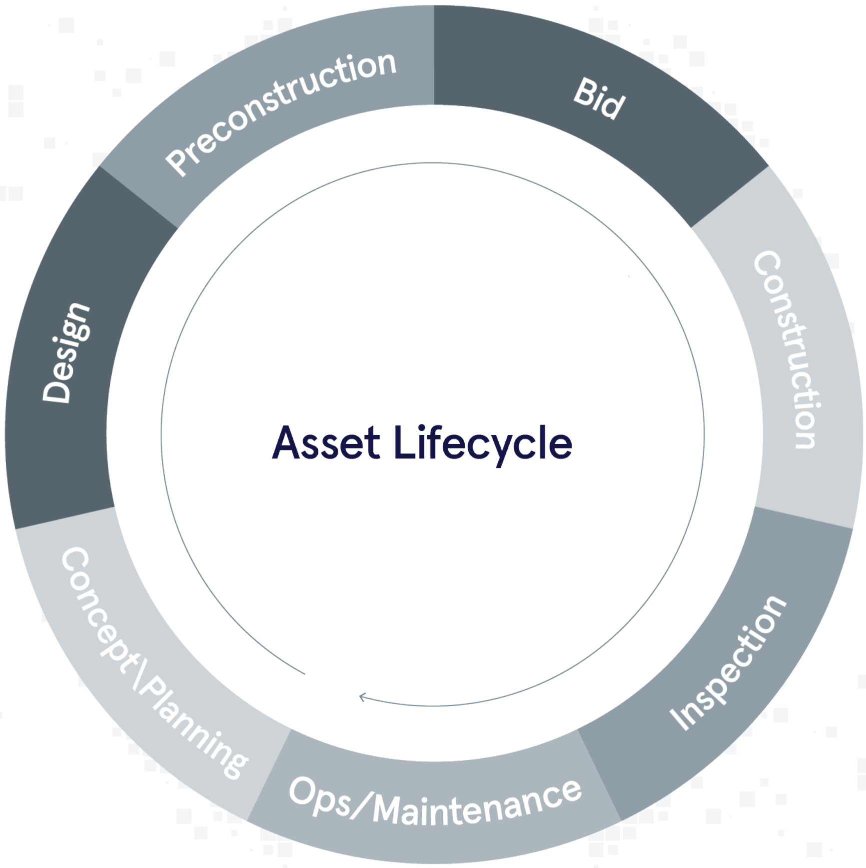


IOWA DOT
ROADMAP FOR DIGITAL DELIVERY
Pilot Projects: Earthwork 3D Models FIO
2006 - 2014
2015
Contractual Earthwork 3D Models
Contractual 3D Model Bridge Pilot Project and Deployment of e-Construction & e-Ticketing
2018 - 2020
Strategic Plan for
BIM for Infrastructure Pooled Fund
Committed States and FHWA
Preliminary Scope of Work
• Develop BIM use case and workflows
• Establish B
• Enhance sk collaboratio
• Deploy data and techniq
• Information
Link - www.pooledfund.org/Details/Study/707
Digital Delivery Directive 2025
ROADMAP
pennsylvania
Our Vision
By 2025, construction projects will be bid using 3D technology and no longer be in a traditional construction plan format
Our Mission
To support the digital transformation of project development within PennDOT developing modeling requirements, processes, and workforce development to enable improved asset information transfer by using 3D data-rich information models
Goals
Implement 3D Technology
Advance the Use of Accessible Digital Processes and Tools
Capture Data-Rich Asset Models
Keys to Success
• Manage Pace of Change
• Help People Perceive Progress
• Create Safe Space for Experimentation
• Empower Pilot Project Teams
• Use Construction Partnering
Strategic Approach
• Assess Stakeholder Needs, Desires and Priorities
• Align Technical Solutions with Stakeholder Input
• Advance Technical Solutions Incrementally
2025
Digital Delivery Implemented
• Standardized Digital Delivery Process
2024
Drainage and Asset Management Requirements
• Modeling Standards
• Education and Training
• Continued Pilot Projects
2023
Bridge and Construction Modeling Requirements
• Modeling Standards
• Education and Training
• Continued Pilot Projects
2022
Roadway Modeling Requirements
• Modeling Standards
• Education and Training
• Continued Pilot Projects
2021
Quick Start Tools
• Model Review Checklist
• Procurement Language
• Project Execution Plan Template
• ConceptStation Pilot
• Guiderail As-built Pilot
2020
Strategic Plan
• Stakeholder Workshops
• Implementation Plan
• Digital Delivery Web Page
• Communication Plan
Email: RA-PDDIGITALDELIVERY@pa.gov

Asset Lifecycle

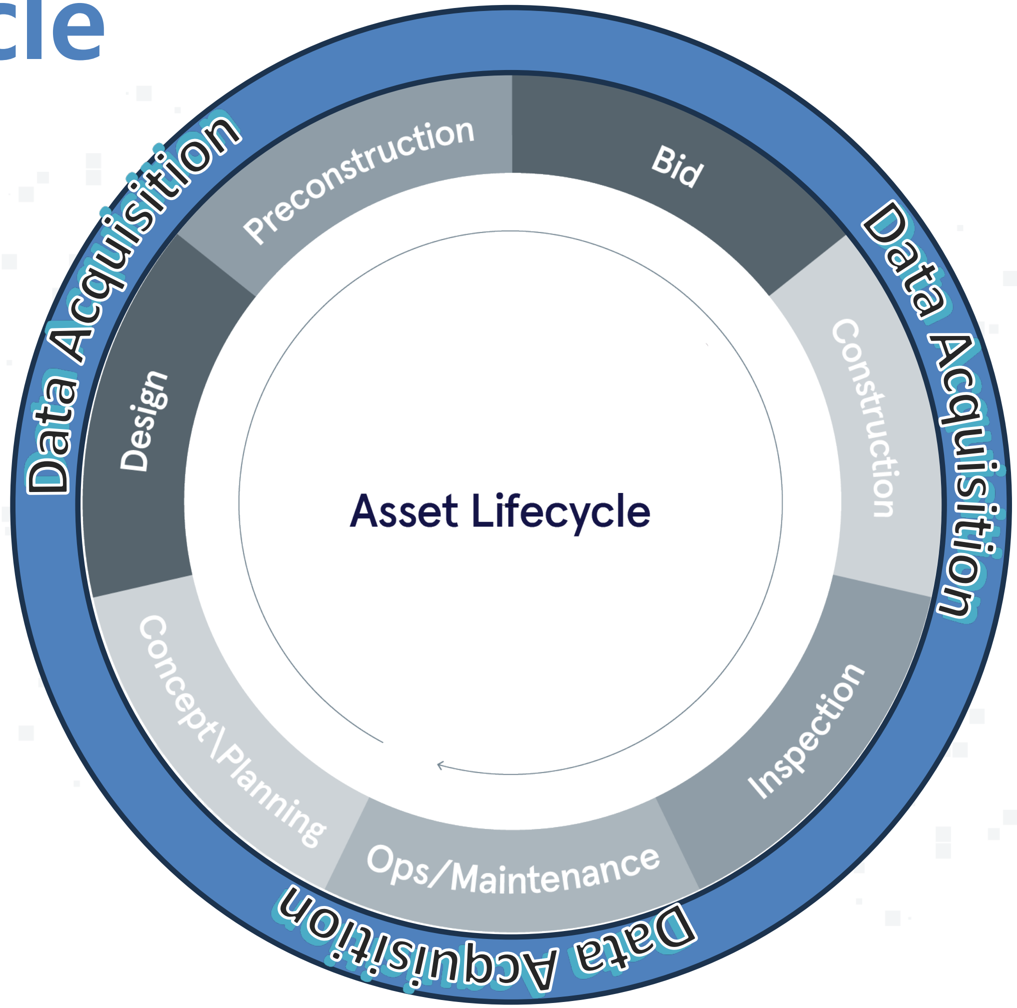


Asset Lifecycle

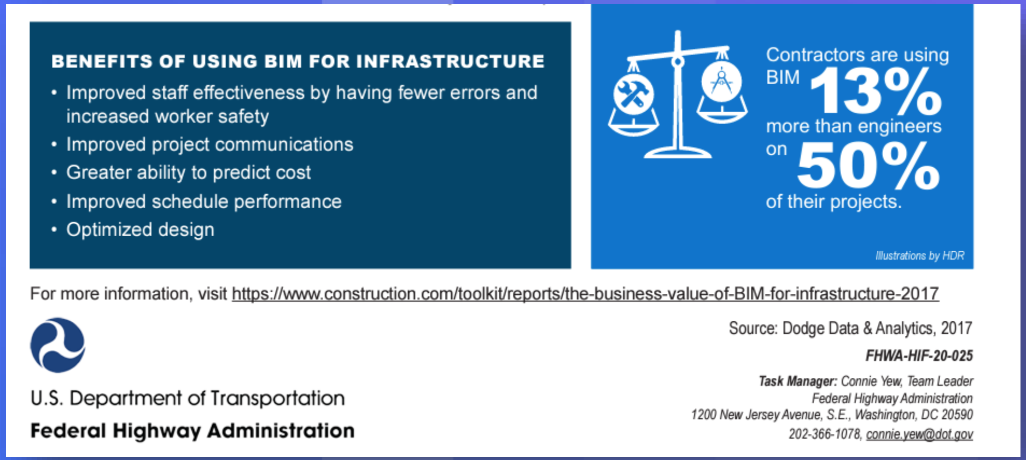


Are you still with me?

Asset Lifecycle



Are you still with me?


BENEFITS OF USING BIM FOR INFRASTRUCTURE

- Improved staff effectiveness by having fewer errors and increased worker safety
- Improved project communications
- Greater ability to predict cost
- Improved schedule performance
- Optimized design

Contractors are using BIM **13%** more than engineers on **50%** of their projects.

Illustrations by HDR

For more information, visit https://www.construction.com/toolkit/reports/the-business-value-of-BIM-for-infrastructure-2017

Source: Dodge Data & Analytics, 2017

FHWA-HIF-20-025

U.S. Department of Transportation

Federal Highway Administration

__Task Manager:__ Connie Yew, Team Leader
Federal Highway Administration
1200 New Jersey Avenue, S.E., Washington, DC 20590
202-366-1078, connie.yew@dot.gov

BIM

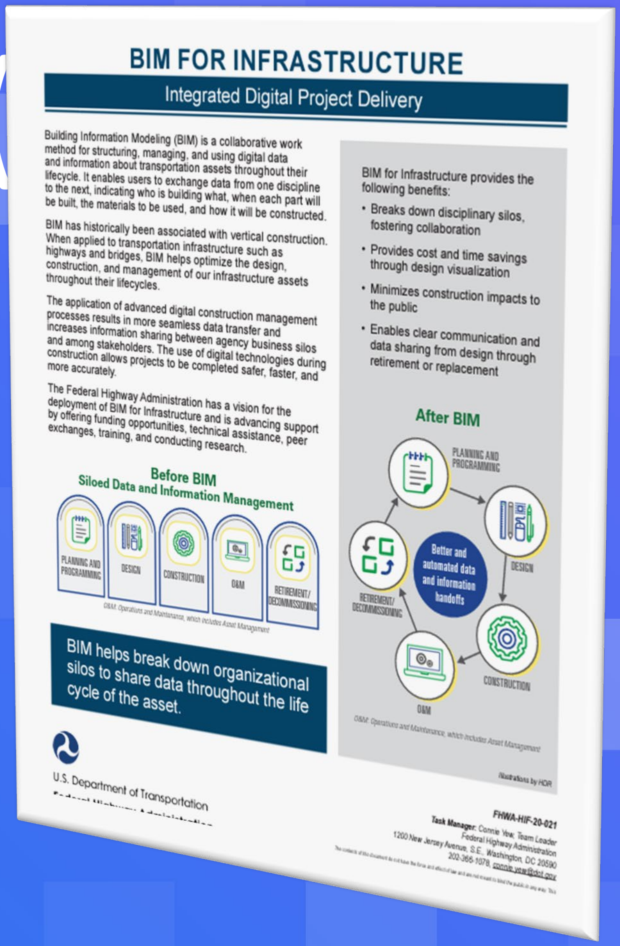
Modeling and improving information flow throughout the construction lifecycle. Originally, the term applied to building construction projects, but it now encompasses infrastructure through to operations and maintenance.*

*buildingSmart - Australia

infotech®

Digital Project Delivery (

- The effective use of digital data to design, construct, inspect and record as-built conditions during the delivery of a construction project.
- BIM and DPD are not unrelated



BIM FOR INFRASTRUCTURE

Integrated Digital Project Delivery

Building Information Modeling (BIM) is a collaborative work method for structuring, managing, and using digital data and information about transportation assets throughout their lifecycle. It enables users to exchange data from one discipline to the next, indicating who is building what, when each part will be built, the materials to be used, and how it will be constructed.

BIM has historically been associated with vertical construction. When applied to transportation infrastructure such as highways and bridges, BIM helps optimize the design, construction, and management of our infrastructure assets throughout their lifecycles.

The application of advanced digital construction management processes results in more seamless data transfer and increases information sharing between agency business silos and among stakeholders. The use of digital technologies during construction allows projects to be completed safer, faster, and more accurately.

The Federal Highway Administration has a vision for the deployment of BIM for Infrastructure and is advancing support by offering funding opportunities, technical assistance, peer exchanges, training, and conducting research.

BIM for Infrastructure provides the following benefits:

- Breaks down disciplinary silos, fostering collaboration
- Provides cost and time savings through design visualization
- Minimizes construction impacts to the public
- Enables clear communication and data sharing from design through retirement or replacement

BIM helps break down organizational silos to share data throughout the life cycle of the asset.

U.S. Department of Transportation

FHWA-HIF-20-021

Task Manager: Connie Yew, Team Leader
Federal Highway Administration
1200 New Jersey Avenue, S.E., Washington, DC 20590
202-366-1078, connie.yew@dot.gov

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Where we are ?

Where do we need to do?

Mind the Gap

- Integration
- Federation
- Collaboration
- Data provenance
- Data governance

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Resolving Ambiguities Between 3D Virtual Models and the Real World

Ron Gant

Infotech

TRB Webinar

"Resolving ambiguities between 3D virtual models and the real world"

David B. Zilkoski
Geodesist

My Role in this Webinar

Survey/Geodesy Perspective

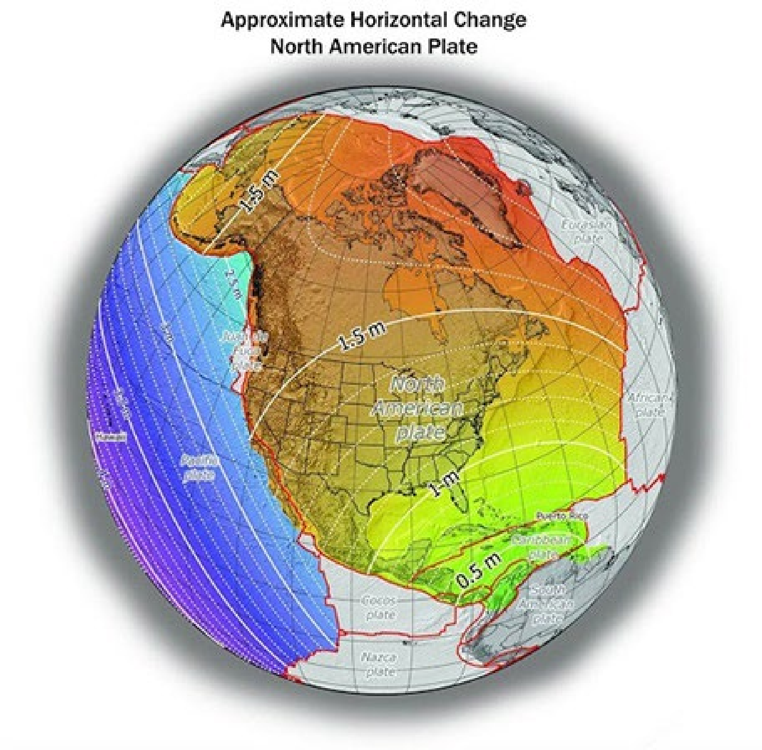
- **Explaining the ambiguities between the 3D virtual model**
  - **Digital Plans, Real World, and Geospatial Technology**
    - **Current Standard for Measurement and Location Technology**

Outline of Presentation

- New, Modernized National Spatial Reference System (NSRS)
  - Current Reference System versus Future Reference System
- Various Types of Coordinates for the Same Mark (Location)
  - Geodetic Coordinates, State Plane Coordinates, Cartesian Coordinates
- Geospatial Products in Difference Reference Frames
  - Transformation Between Reference Frames and Coordinate Types

New Datums Will Replace NAD 83 and NAVD 88

- **NAD 83 and NAVD 88 have been identified as having shortcomings that are best addressed through defining new a Reference Frame System:**
  - **NAD 83 is non-geocentric by about 2.2 meters**
  - **NAD 83 is not well defined with positional velocities**
  - **NAVD 88 is biased and tilted**
  - **The new modernized reference frames will be easier to *access* and to *maintain* than NAD 83 and NAVD 88**

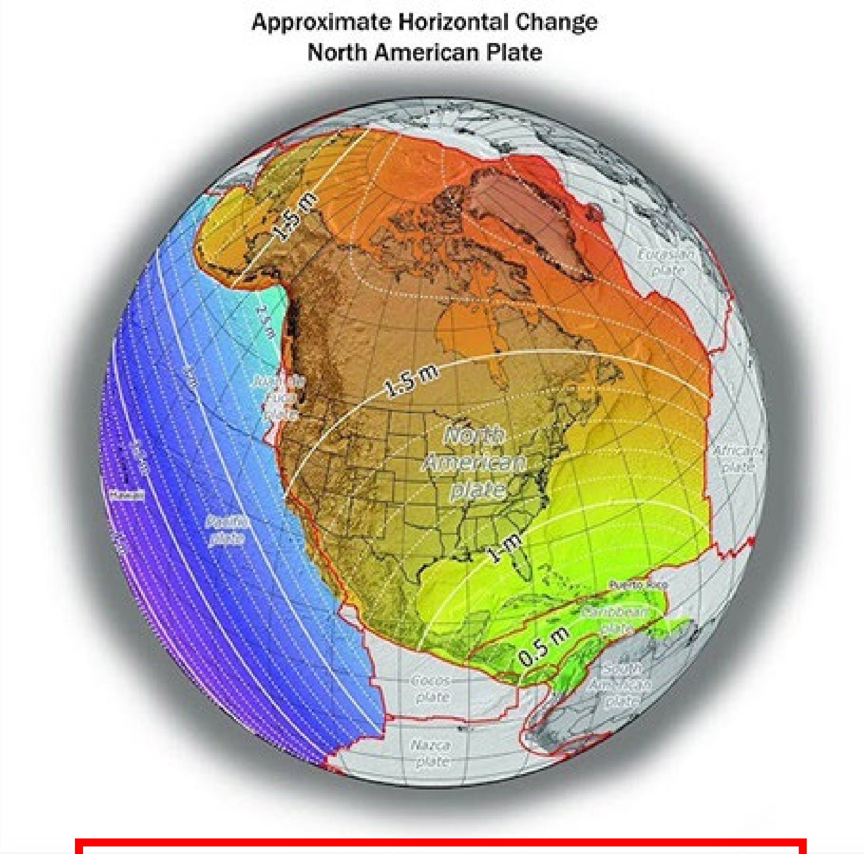


~1 to 1.5 meters North America
~2.5 to 4 meters in Pacific

Picture from Jacob M. Heck-apr2019_mtu_ngs_presentation

The New, Modernized National Spatial Reference System 2022

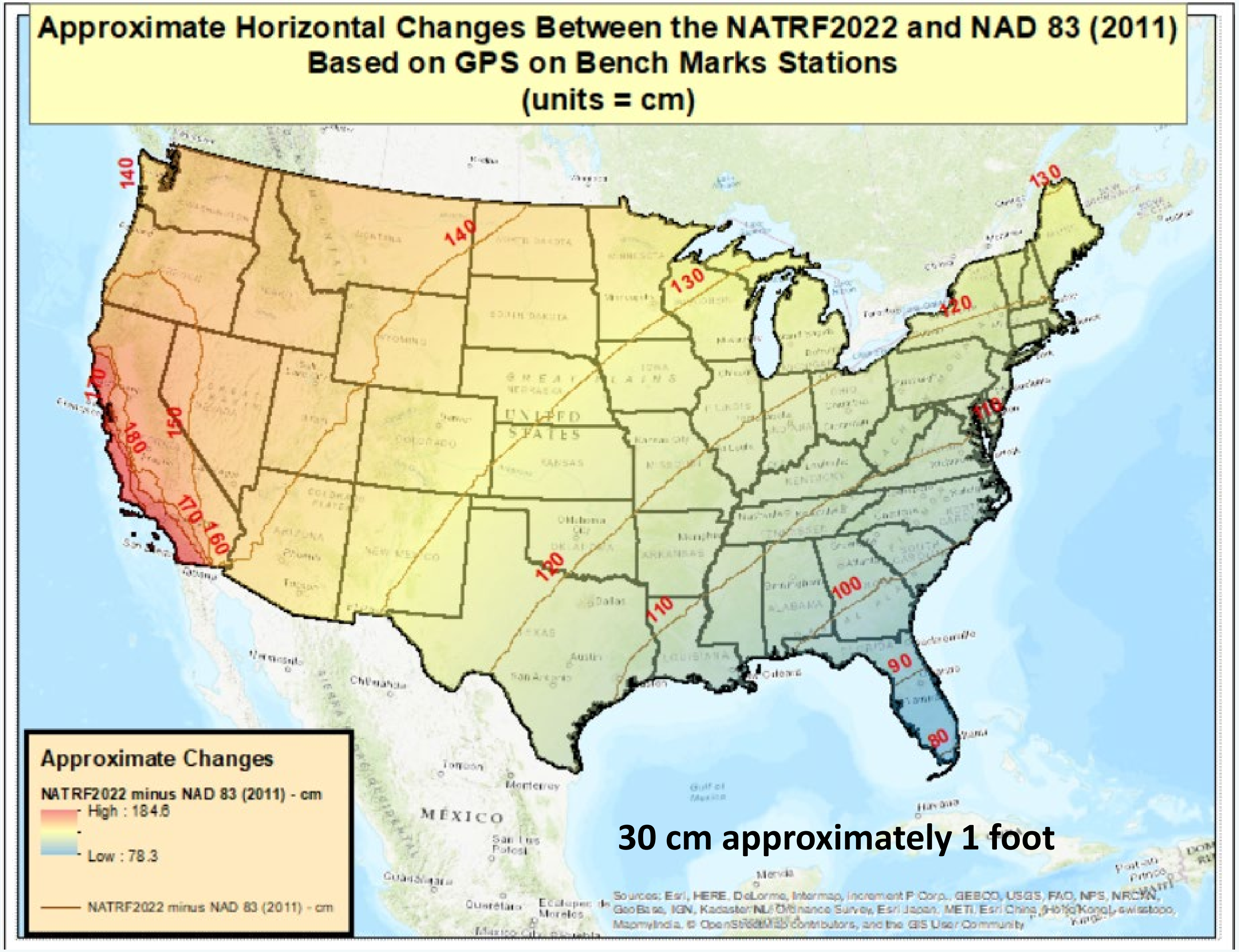
- Definition of the National Spatial Reference System (NSRS)
  - Current Reference System versus Future Reference System
    - What are the expected coordinate changes?



- **NAD 83 is non-geocentric by about 2.2 meters**

~1 to 1.5 meters North America
~2.5 to 4 meters in Pacific

Picture from Jacob M. Heck- apr2019_mtu_ngs_presentation



What are the expected coordinate changes in the Conterminous United States?

This is based on the GPS on Bench Marks Stations involved in GEOID18 using NAD 83 (2011) Epoch 2010.00 and IGS2014 Epoch 2020.00 Coordinates

- **Fairly smooth change except in California**
  - **Surveyors will be using PATRF2022 in parts of California**

The New NSRS Will Replace NAVD 88

- NAVD 88 is biased (by ≈ one-half meter) and tilted (≈ a meter coast to coast)

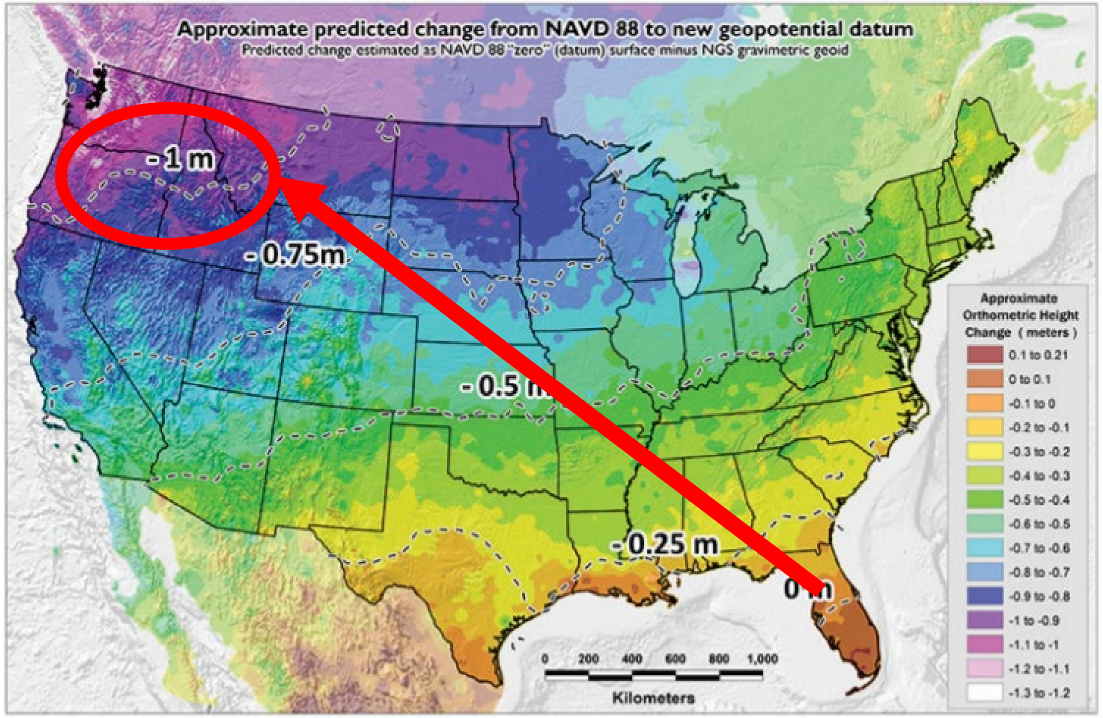


Figure 1: The continental bias and tilt of the NAVD 88 H=0 surface across CONUS as implied by the latest NGS experimental geoid model based on improved gravity data.

30 cm approximately 1 foot

Figure from NOAA Technical Report NOS NGS 64, Revised February 2021 Version

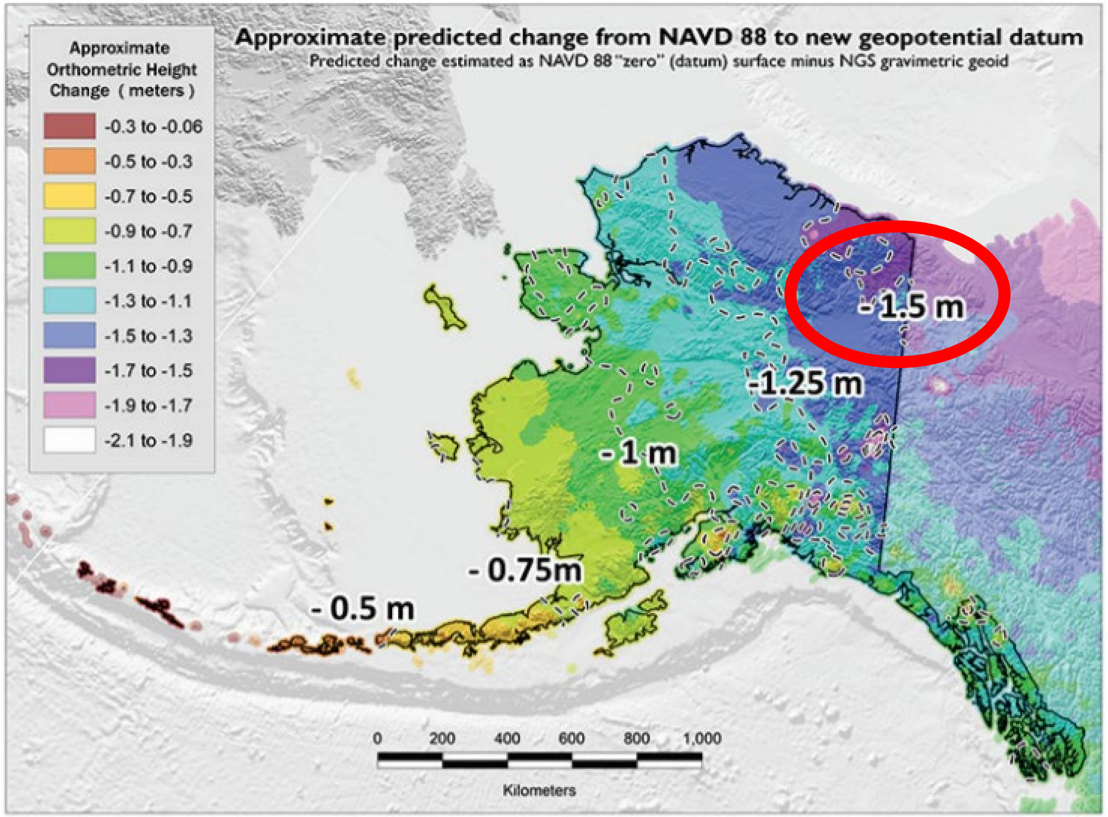


Figure 2: The statewide bias and tilt of the NAVD 88 H=0 surface across Alaska as implied by the latest NGS experimental geoid model based on improved gravity data. Note the tilt is due to the severely poor distribution and quality of GNSS on Bench Mark data

- ***There are Various Types of Coordinates for the Same Mark***
  - ***Latitude, Longitude, Ellipsoid Height, Orthometric Height***
  - ***State Plane Coordinates (Northing, Easting or y,x)***
  - ***Cartesian Coordinates (X,Y,Z)***
- ***Need the follow adopted data governance that include the appropriate metadata to perform conversions and transformations***
  - ***Data governance is a set of processes, policies, and standards that ensure data is secure, accurate, and usable throughout its lifecycle***

Different Coordinate Types for the same Mark – Jacksonville NC CORS ARP

NGS Datasheet

The NGS Data Sheet
See file dsdata.pdf for more information about the datasheet.
PROGRAM = datasheet95, VERSION = 8.12.5.19
Starting Datasheet Retrieval...
1 National Geodetic Survey, Retrieval Date = NOVEMBER 5, 2024 09:30:55 EST
DK6239 ***
DK6239 HT_MOD - This is a Height Modernization Survey Station.
DK6239 CORS - This is a GPS Continuously Operating Reference Station.
DK6239 DESIGNATION - JACKSONVILLE CORS ARP
DK6239 CORS_ID - NCJV
DK6239 PID - DK6239
DK6239 STATE/COUNTY- NC/ONSLOW
DK6239 COUNTRY - US
DK6239 USGS QUAD - JACKSONVILLE SOUTH (2019)
DK6239
DK6239 *CURRENT SURVEY CONTROL
DK6239 ____
DK6239* NAD 83(2011) POSITION- 34 44 46.81578(N) 077 27 11.71801(W) ADJUSTED
DK6239* NAD 83(2011) ELLIP HT- -26.123 (meters) (06/??/19) ADJUSTED
DK6239* NAD 83(2011) EPOCH - 2010.00
DK6239* NAVD 88 ORTHO HEIGHT - 10.95 (meters) 35.9 (feet) GPS OBS
DK6239 ____
DK6239 NAVD 88 orthometric height was determined with an earlier geoid model
DK6239 GEOID HEIGHT - -37.057 (meters) GEOID18
DK6239 NAD 83(2011) X - 1,139,727.935 (meters) COMP
DK6239 NAD 83(2011) Y - -5,121,204.192 (meters) COMP
DK6239 NAD 83(2011) Z - 3,614,764.731 (meters) COMP
DK6239
DK6239 Network accuracy estimates per FGDC Geospatial Positioning Accuracy
DK6239 Standards:
DK6239 FGDC (95% conf, cm) Standard deviation (cm) CorrNE
DK6239 Horiz Ellip SD_N SD_E SD_h (unitless)
DK6239 ---
DK6239 NETWORK 0.13 0.26 0.03 0.06 0.14 -0.26358000
DK6239 ---

Latitude, Longitude, Ellipsoid Height,and Orthometric Height

NAD 83 (2011) Cartesian Coordinates (X,Y,Z)

State Plane Coordinates

DK6239
DK6239. The following values were computed from the NAD 83(2011) position.
DK6239
DK6239; North East Units Scale Factor Converg.
DK6239;SPC NC - 111,628.028 751,216.796 MT 0.99991124 +0 53 33.8
DK6239;SPC NC - 366,232.96 2,464,617.10 sFT 0.99991124 +0 53 33.8
DK6239;UTM 18 - 3,847,654.691 275,423.535 MT 1.00022166 -1 23 55.7
DK6239
DK6239! - Elev Factor x Scale Factor = Combined Factor
DK6239!SPC NC - 1.00000410 x 0.99991124 = 0.99991534
DK6239!UTM 18 - 1.00000410 x 1.00022166 = 1.00022576
DK6239
DK6239_U.S. NATIONAL GRID SPATIAL ADDRESS: 18STD7542347654(NAD 83)

Same Mark

- ***Different Types of Coordinate***

Different Coordinate Types for the same Mark – Jacksonville NC CORS ARP

```
The NGS Data Sheet
See file dsdata.pdf for more information about the datasheet.
PROGRAM = datasheet95, VERSION = 8.12.5.19
Starting Datasheet Retrieval...
1    National Geodetic Survey, Retrieval Date = NOVEMBER  5, 2024 09:30:55 EST
 DK6239 ***********************************************************************
 DK6239  HT_MOD      -  This is a Height Modernization Survey Station.
 DK6239  CORS        -  This is a GPS Continuously Operating Reference Station.
 DK6239  DESIGNATION -  JACKSONVILLE CORS ARP
 DK6239  CORS_ID     -  NCJV
 DK6239  PID         -  DK6239
 DK6239  STATE/COUNTY-  NC/ONSLOW
 DK6239  COUNTRY     -  US
 DK6239  USGS QUAD   -  JACKSONVILLE SOUTH (2019)
 DK6239
 DK6239                    *CURRENT SURVEY CONTROL
 DK6239 ___________________________________________________________________
 DK6239* NAD 83(2011) POSITION- 34 44 46.81578(N) 077 27 11.71801(W)   ADJUSTED
 DK6239* NAD 83(2011) ELLIP HT-   -26.123 (meters)        (06/??/19)   ADJUSTED
 DK6239* NAD 83(2011) EPOCH  -  2010.00
 DK6239* NAVD 88 ORTHO HEIGHT -    10.95  (meters)       35.9   (feet) GPS OBS
 DK6239 ___________________________________________________________________
 DK6239  NAVD 88 orthometric height was determined with an earlier geoid model
 DK6239  GEOID HEIGHT    -        -37.057 (meters)                 GEOID18
 DK6239  NAD 83(2011) X  -  1,139,727.935 (meters)                 COMP
 DK6239  NAD 83(2011) Y  - -5,121,204.192 (meters)                 COMP
 DK6239  NAD 83(2011) Z  -  3,614,764.731 (meters)                 COMP
 DK6239

 ITRF2014 POSITION (EPOCH 2010.0)
 Computed in Jun 2019 using data through gpswk 1933.
     X =    1139727.193 m     latitude     =  34 44 46.84262 N
     Y =   -5121202.689 m     longitude    = 077 27 11.73365 W
     Z =    3614764.608 m     ellipsoid height =  -27.530    m

 DK6239 -------------------------------------------------------------------
```

```
DK6239
 DK6239. The following values were computed from the NAD 83(2011) position.
 DK6239
 DK6239;              North        East     Units Scale Factor Converg.
 DK6239;SPC NC      -  111,628.028   751,216.796   MT  0.99991124   +0 53 33.8
 DK6239;SPC NC      -  366,232.96  2,464,617.10   sFT  0.99991124   +0 53 33.8
 DK6239;UTM  18     - 3,847,654.691   275,423.535   MT  1.00022166   -1 23 55.7
 DK6239
 DK6239!            -  Elev Factor  x  Scale Factor =   Combined Factor
 DK6239!SPC NC      -  1.00000410  x  0.99991124  =  0.99991534
 DK6239!UTM  18     -  1.00000410  x  1.00022166  =  1.00022576
 DK6239
 DK6239_U.S. NATIONAL GRID SPATIAL ADDRESS: 18STD7542347654(NAD 83)
```

ITRF 2014
Cartesian Coordinates
(X,Y,Z)

Different Coordinate Types for the same Mark – Jacksonville NC CORS ARP

The NGS Data Sheet
See file dsdata.pdf for more information about the datasheet.
PROGRAM = datasheet95, VERSION = 8.12.5.19
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DK6239 DESIGNATION - JACKSONVILLE CORS ARP
DK6239 CORS_ID - NCJV
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DK6239 STATE/COUNTY- NC/ONSLOW
DK6239 COUNTRY - US
DK6239 USGS QUAD - JACKSONVILLE SOUTH (2019)
DK6239
DK6239 *CURRENT SURVEY CONTROL
DK6239 ____
DK6239* NAD 83(2011) POSITION- 34 44 46.81578(N) 077 27 11.71801(W) ADJUSTED
DK6239* NAD 83(2011) ELLIP HT- -26.123 (meters) (06/??/19) ADJUSTED
DK6239* NAD 83(2011) EPOCH - 2010.00
DK6239* NAVD 88 ORTHO HEIGHT - 10.95 (meters) 35.9 (feet) GPS OBS
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DK6239 NAD 83(2011) Y - -5,121,204.192 (meters) COMP
DK6239 NAD 83(2011) Z - 3,614,764.731 (meters) COMP
DK6239

ITRF2014 POSITION (EPOCH 2010.0)
Computed in Jun 2019 using data through gpswk 1933.
X = 1139727.193 m latitude = 34 44 46.84262 N
Y = -5121202.689 m longitude = 077 27 11.73365 W
Z = 3614764.608 m ellipsoid height = -27.530 m

DK6239 ---

DK6239
DK6239. The following values were computed from the NAD 83(2011) position.
DK6239
DK6239; North East Units Scale Factor Converg.
DK6239;SPC NC - 111,628.028 751,216.796 MT 0.99991124 +0 53 33.8
DK6239;SPC NC - 366,232.96 2,464,617.10 sFT 0.99991124 +0 53 33.8
DK6239;UTM 18 - 3,847,654.691 275,423.535 MT 1.00022166 -1 23 55.7
DK6239
DK6239! - Elev Factor x Scale Factor = Combined Factor
DK6239!SPC NC - 1.00000410 x 0.99991124 = 0.99991534
DK6239!UTM 18 - 1.00000410 x 1.00022166 = 1.00022576
DK6239
DK6239_U.S. NATIONAL GRID SPATIAL ADDRESS: 18STD7542347654(NAD 83)

New NSRS in 2025

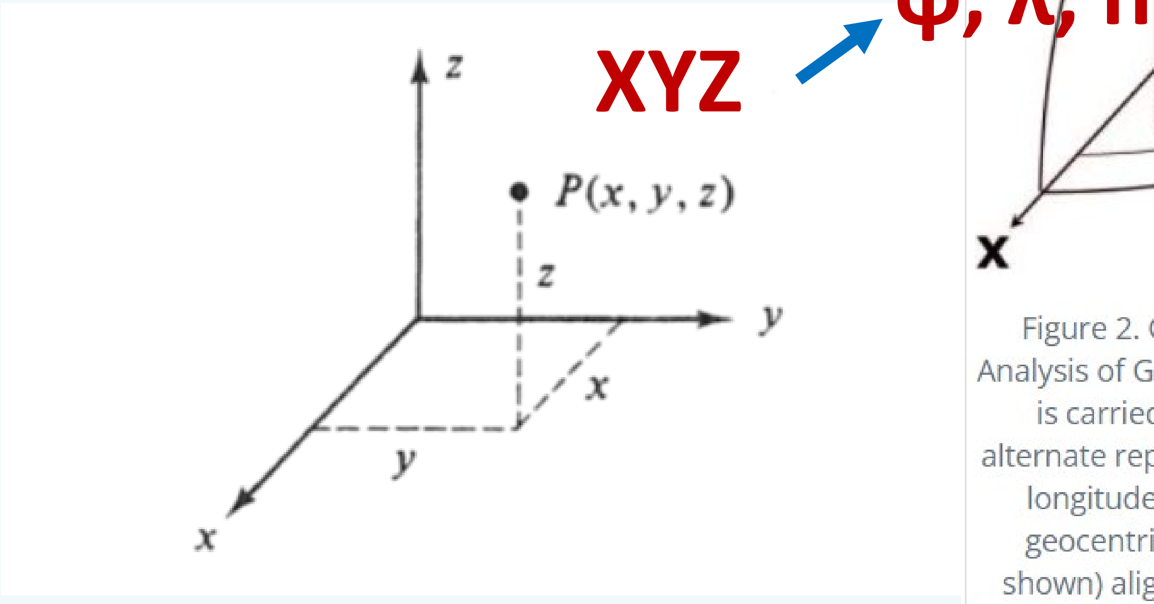
ITRF2020 Position (Epoch 2020.0)

NATRF2022 Position (Epoch 2020.0)

Between Coordinate Types

Simple Conversion Process

"XYZ" to "ϕ, λ, h" to "NEU"



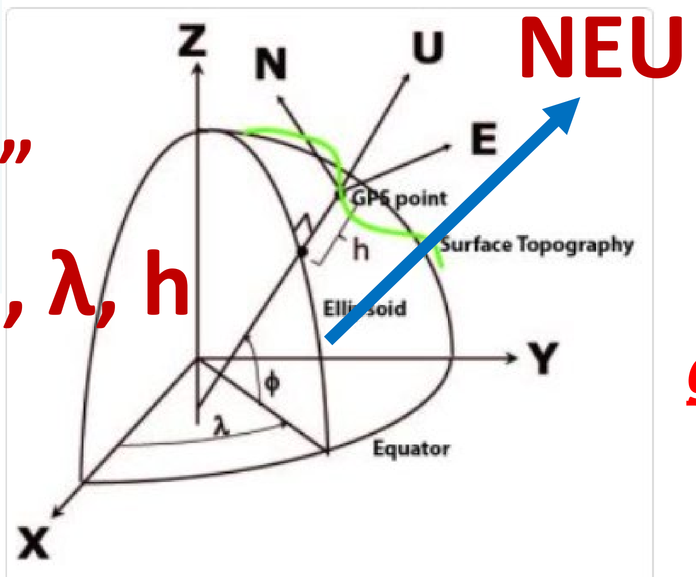


Figure 2. Geodetic coordinate systems. Analysis of GPS phase and pseudorange data is carried out in ITRF coordinates. An alternate representation is geodetic latitude, longitude and height with respect to a geocentric oblate ellipsoid (one octant shown) aligned with the zero meridian (X-axis) and pole (Z-axis). (Bock and Melgar, 2016)

It is important to have the *appropriate data governance and metadata* to perform the transformations and conversions

Between Coordinate Types and Reference Frames

It is important to have the *appropriate data governance and metadata* to perform the transformations and conversions

NOTE: It is not necessary to know these equations

Seven-Parameter Transformation

The seven-parameter transformation defines the translation, rotation and scale change between the origins and axes of the ellipsoids used for each datum.

$$X' = (1 + \Delta L) * X + R_Z * Y - R_Y * Z + T_X$$
$$Y' = (1 + \Delta L) * Y - R_Z * X + R_X * Z + T_Y$$
$$Z' = (1 + \Delta L) * Z + R_Y * X - R_X * Y + T_Z$$

Where X, Y, Z are the original coordinates, T_X, T_Y, T_Z are the translation parameters, R_X, R_Y, R_Z are the rotation parameters, and ΔL (or ΔS) is the scale change.

In this case, we have two parameters per axis, as well as a scale change, totaling seven parameters.

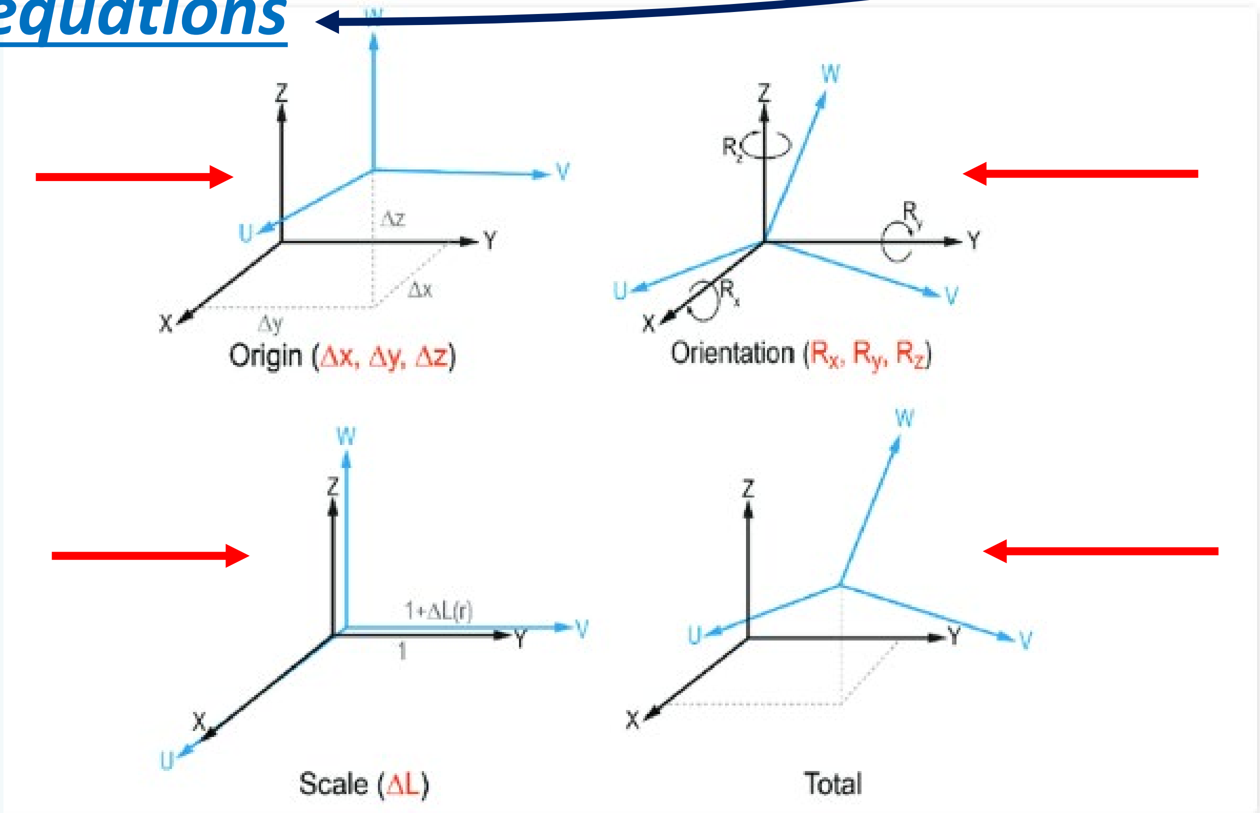


Diagram and Equations from ESRI AustraliaTechnical Blog

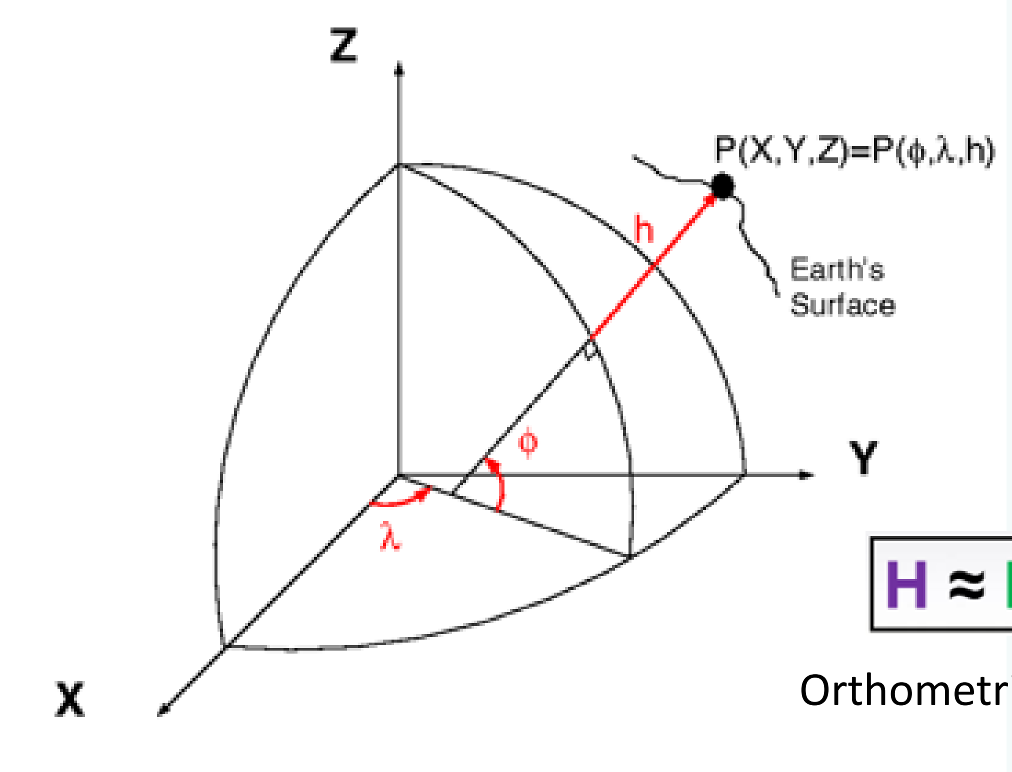
https://esriaustraliatechblog.wordpress.com/2023/12/11/what-is-a-datum-transformation-and-how-does-it-work/

Integrate CAD Drawings into Geodetic Reference System

What about the Orthometric Height?

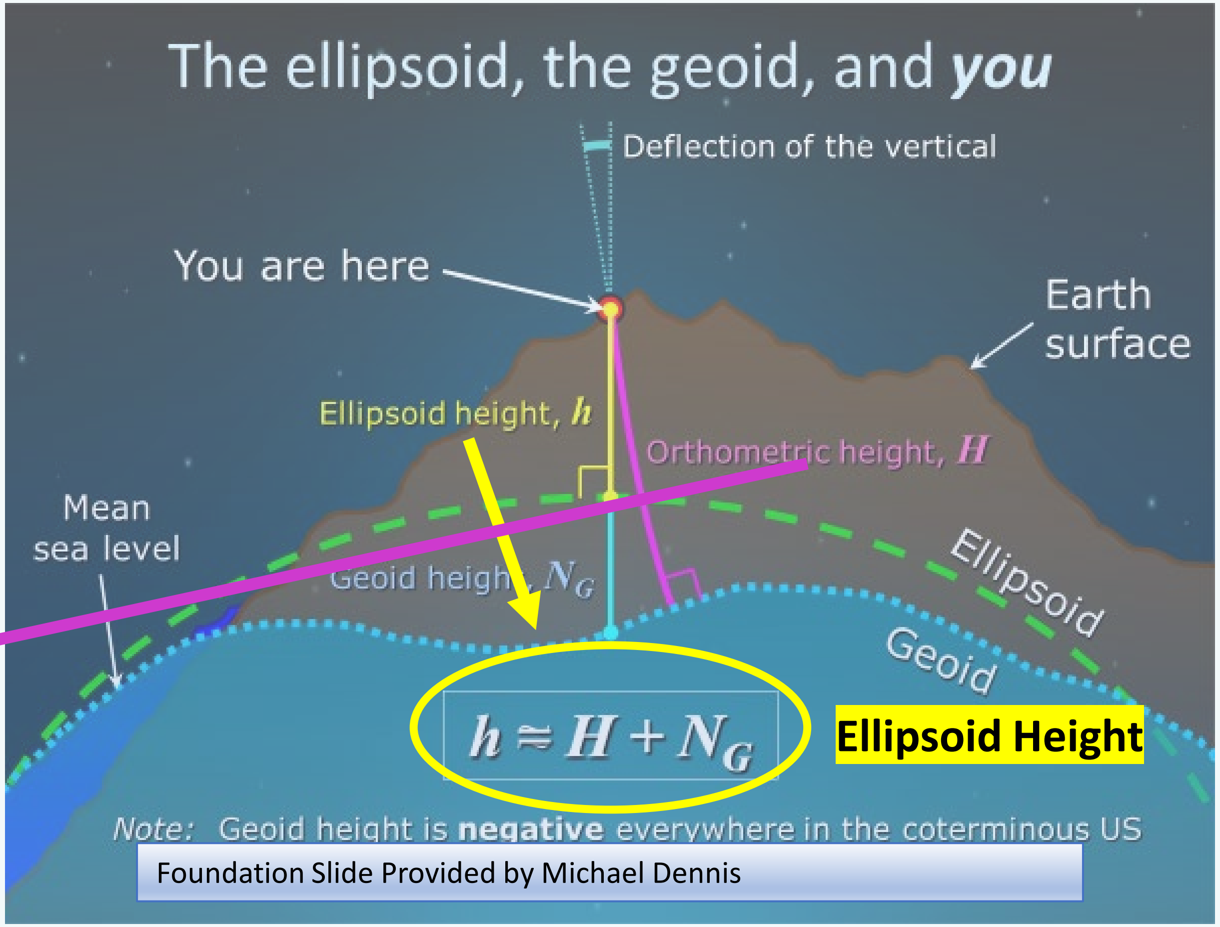
Ellipsoid Height and Orthometric Height are not measured along the same path or from the same reference surface

The Geoid can be modeled from gravity data as they are mathematically related



H ≈ h - N

Orthometric Height



Ellipsoid Height

Single Point Conversion | Multipoint Conversion | Web services | Downloads | Tutorial & FAQs | About NCAT

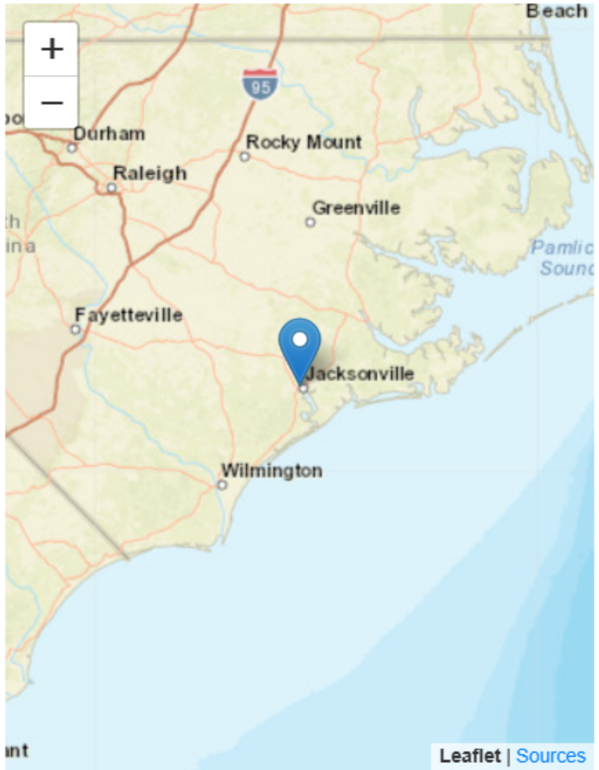
Tools are available to convert and transform coordinates between reference frames and coordinate types

NCAT – Transform Geodetic Coordinates Between Reference Frames

Convert/Transform from: ☐ Horizontal ◉ Horizontal+height ☐ XYZ

Select the type of horizontal coordinate: ◉ Geodetic lat-long ☐ SPC ☐ UTM ☐ USNG

Select a height: ◉ Ellipsoidal ☐ Orthometric



Enter lat-lon in decimal degrees

Lat: 34.7463377667

Lon: -77.4532551722

or degrees-minutes-seconds

Lat: N 34-44-46.81596

Lon: W 077-27-11.71862

or drag map marker to a location of interest

Ellipsoid Height: -26.094

Units of height: Meters

Input reference frame (historically called 'horizontal datum'): NAD83(NSRS2007)

Output reference frame (historically called 'horizontal datum'): NAD83(2011)

Don't see a reference frame in the list? Click **here** *to learn more.*

SPC zone: Auto Pick (default zor

Submit

There are Various Types of Coordinates for the Same Mark

Same Mark

- ***Different Types of Coordinate***
  - **Latitude, Longitude, Ellipsoid Height**

Transformed Coordinate

Input Coordinate		Output Coordinate		Total Change + Uncertainty	
Latitude	N34° 44′ 46.81596″ N344446.81596 34.7463377667	Latitude	N34° 44′ 46.81580″ N344446.81580 34.7463377212	Latitude	-0.00016″ ±0.000200″ (-0.005 m ±0.0062 m)*
Longitude	E282° 32′ 48.28138″ W0772711.71862 -77.4532551722	Longitude	E282° 32′ 48.28192″ W0772711.71808 -77.4532550235	Longitude	0.00054″ ±0.000234″ (0.014 m ±0.0060 m)*
Ellipsoid Height (m)	-26.094	Ellipsoid Height (m)	-26.103	Ellipsoid Height	-0.009 m ±0.004 m
Orthometric Height (m)	Not given	Orthometric Height (m)	Not given	Orthometric Height	Not given
Reference Frame	NAD83(NSRS2007)	Reference Frame	NAD83(2011)		
Geopotential Datum	Not given	Geopotential Datum	Not given		

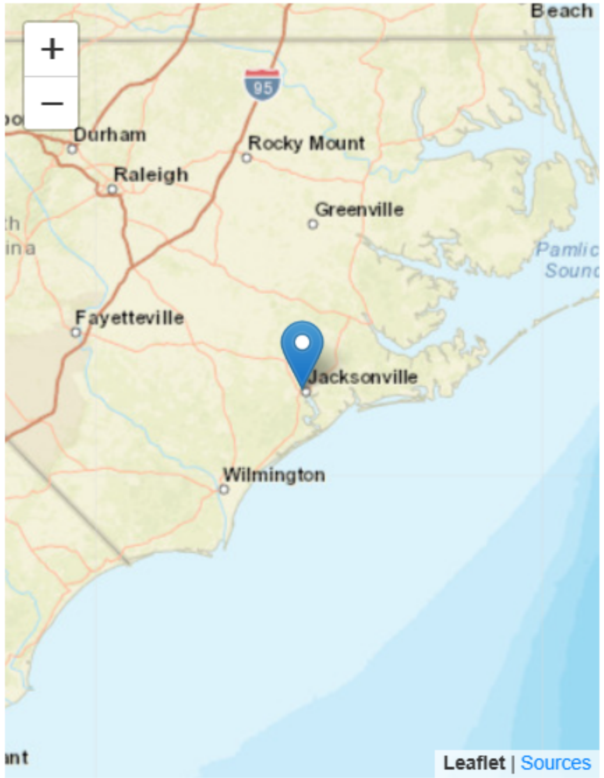
*Approximate value to aid interpretation and not an actual distance. See **TM NOS NGS 82** for more details.

Single Point Conversion | Multipoint Conversion | Web services | Downloads | Tutorial & FAQs | About NCAT

Convert/Transform from: ○ Horizontal ● Horizontal+height ○ XYZ

Select the type of horizontal coordinate: ● Geodetic lat-long ○ SPC ○ UTM ○ USNG

Select a height ● Ellipsoidal ○ Orthometric



Enter lat-lon in decimal degrees

Lat 34.7463377167

Lon -77.4532550028

or degrees-minutes-seconds

Lat N 34-44-46.81578

Lon W 077-27-11.71801

or drag map marker to a location of interest

Ellipsoid Height -26.123

Units of height Meters

Input reference frame (historically called 'horizontal datum') NAD83(2011)

Output reference frame (historically called 'horizontal datum') NAD83(2011)

Don't see a reference frame in the list? Click **here** *to learn more.*

SPC zone Auto Pick (default zor

Submit

NCAT – Convert Geodetic Coordinates

- **Lat-Long-height**
- **State Plane**
- **XYZ**

There are Various Types of Coordinates for the Same Mark

Same Mark

- ***<u>Different Types of Coordinate</u>***
  - **Latitude, Longitude, Ellipsoid Height**
  - **State Plane Coordinates (Northing, Easting or y,x)**
  - **Cartesian Coordinates (X,Y,Z)**

Click blue bar(s) to expand/collapse

Converted Coordinate

Reference Frame:NAD83(2011)

Lat-Lon-Height

Latitude	N34° 44′ 46.81578″ N344446.81578 34.7463377167
Longitude	E282° 32′ 48.28199″ W0772711.71801 -77.4532550028
Ellipsoid Height (m)	-26.123

SPC

Zone	NC-3200
Northing	111,628.028 (m) 366,232.956 (usft) 366,233.688 (ift)
Easting	751,216.796 (m) 2,464,617.106 (usft) 2,464,622.035 (ift)
Convergence (dms)	00 53 33.85
Scale factor	0.99991124
Combined factor	0.99991534

UTM/USNG

Zone	18
Northing (m)	3,847,654.691
Easting (m)	275,423.535
Convergence (dms)	-01 23 55.69
Scale factor	1.00022166
Combined factor	1.00022576
USNG	18STD7542447655

XYZ (m)

X	1,139,727.935
Y	-5,121,204.192
Z	3,614,764.731

You may change the default UTM zone. The change is processed interactively once a lat-long is converted; DO NOT click the Submit button.

Key Take Aways

Different Coordinate Types for the same Mark – Jacksonville NC CORS ARP

1 National Geodetic Survey, Retrieval Date = NOVEMBER 5, 2024 09:30:55 EST
DK6239 ***
DK6239 HT_MOD - This is a Height Modernization Survey Station.
DK6239 CORS - This is a GPS Continuously Operating Reference Station.
DK6239 DESIGNATION - JACKSONVILLE CORS ARP
DK6239 CORS_ID - NCJV
DK6239 PID - DK6239
DK6239 STATE/COUNTY- NC/ONSLOW
DK6239 COUNTRY - US
DK6239 USGS QUAD - JACKSONVILLE SOUTH (2019)

State Plane Coordinates 1983

DK6239;	North	East	Units	Scale Factor	Converg.
DK6239;SPC NC -	111,628.028	751,216.796	MT	0.99991124	+0 53 33.8
DK6239;SPC NC -	366,232.96	2,464,617.10	sFT	0.99991124	+0 53 33.8
DK6239;UTM 18 -	3,847,654.691	275,423.535	MT	1.00022166	-1 23 55.7

Geodetic Position in NAD 83 (2011) and NAVD 88

DK6239* NAD 83(2011) POSITION- 34 44 46.81578(N) 077 27 11.71801(W) ADJUSTED
DK6239* NAD 83(2011) ELLIP HT- -26.123 (meters) (06/??/19) ADJUSTED
DK6239* NAD 83(2011) EPOCH - 2010.00
DK6239* NAVD 88 ORTHO HEIGHT - 10.95 (meters) 35.9 (feet) GPS OBS

X Y Z in NAD 83 (2011)

DK6239 NAD 83(2011) X - 1,139,727.935 (meters) COMP
DK6239 NAD 83(2011) Y - -5,121,204.192 (meters) COMP
DK6239 NAD 83(2011) Z - 3,614,764.731 (meters) COMP

X Y Z in ITRF 2014

```
ITRF2014 POSITION (EPOCH 2010.0)
Computed in Jun 2019 using data through gpswk 1933.
    X =   1139727.193 m     latitude     =  34 44 46.84262 N
    Y =  -5121202.689 m     longitude    = 077 27 11.73365 W
    Z =   3614764.608 m     ellipsoid height =  -27.530   m
```

New NSRS in 2025

ITRF2020 Position (Epoch 2020.0)
- Geodetic Position
- XYZ

NATRF2022 Position (Epoch 2020.0)
- Geodetic Position
- XYZ
- State Plane Coordinates 2022

Key Take Aways

- Tools are available to convert and transform coordinates between reference frames and coordinate types

- Products generated using geospatial technologies need to adhere to *adopted data governance* to ensure data is secure, accurate, and usable throughout its lifecycl

- Products can be placed in a common reference frame when the *adopted data governance are adhered to* and the *appropriate metdata* are provided

"UVW to XYZ" And "XYZ" to "ϕ, λ, h" to "NEU"

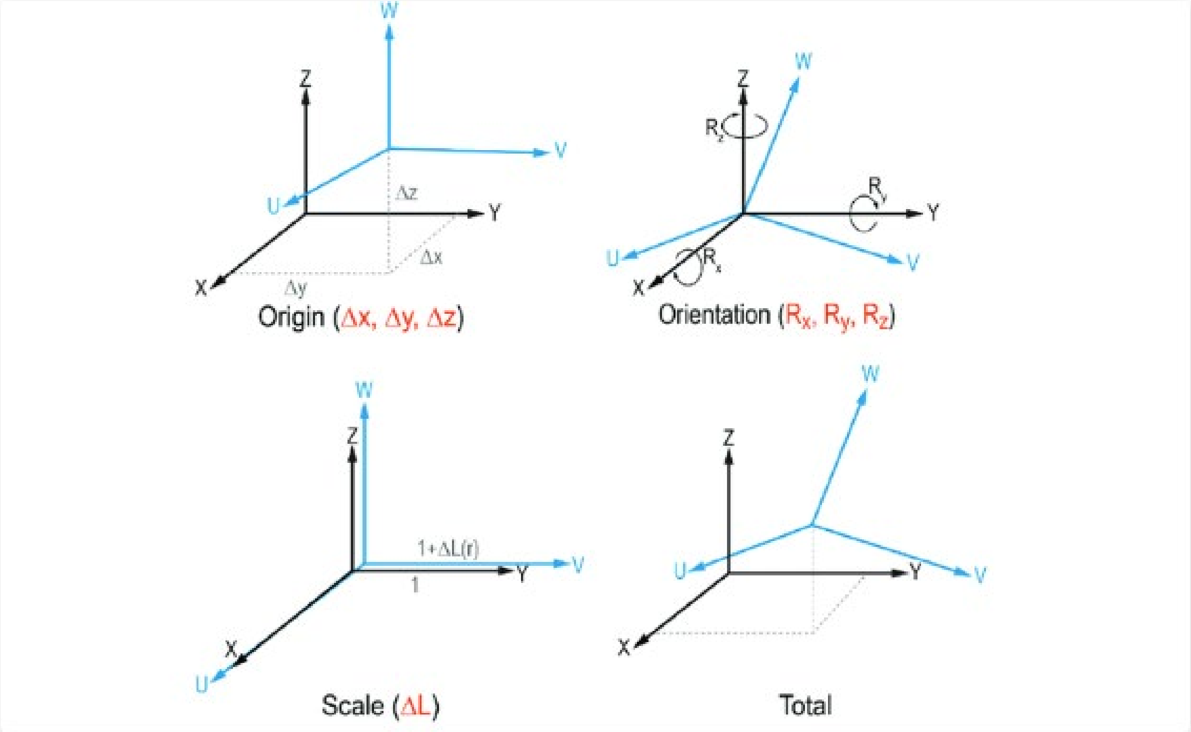


Diagram from ESRI AustraliaTechnical Blog
https://esriaustraliatechblog.wordpress.com/2023/12/11/what-is-a-datum-transformation-and-how-does-it-work/

On Thursday, January 9, 2025, at the Annual Transportation Research Board (TRB) Winter Meeting, there is a Workshop on the Modernized NSRS

Staff Code	Title	Time Slot Display Field	Room Name with Venue
BRW25-0004	Navigating the Modernized National Spatial Reference System: A Geospatial Odyssey	Thursday, Jan 09, 2025 9:00AM - 12:00PM	202B / Convention Center

- The workshop will cover:
  - Why the NSRS is Being Updated
  - The Key Goals of the Modernization Effort
  - Timeline, Standards, and Technology Considerations
  - The Geospatial Data Act of 2018 and its Impact

- There will be discussion about the replacement of the North American Datum of 1983 and vertical datums, and implications for existing workflows.

- There will also be discussion about use cases and practical scenarios, how to transition, and how to leverage new technology and tools.

Today's presenters

Curtis Clabaugh
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David Zilkoski
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Geospatial Solutions by DBZ
Geodesy Provides the Foundation
for all Geospatial Products and Services

Upcoming events for you

December 19, 2024

TRB Webinar: Anticipated Truck Loadings in Pavement Design—Part II

May 27-29, 2025

TRB's Conference on Data and AI for Transportation Advancement

https://www.nationalacademies.org/trb/events

Register for the 2025 TRB Annual Meeting!

January 5 – 9, 2025
Washington, D.C.

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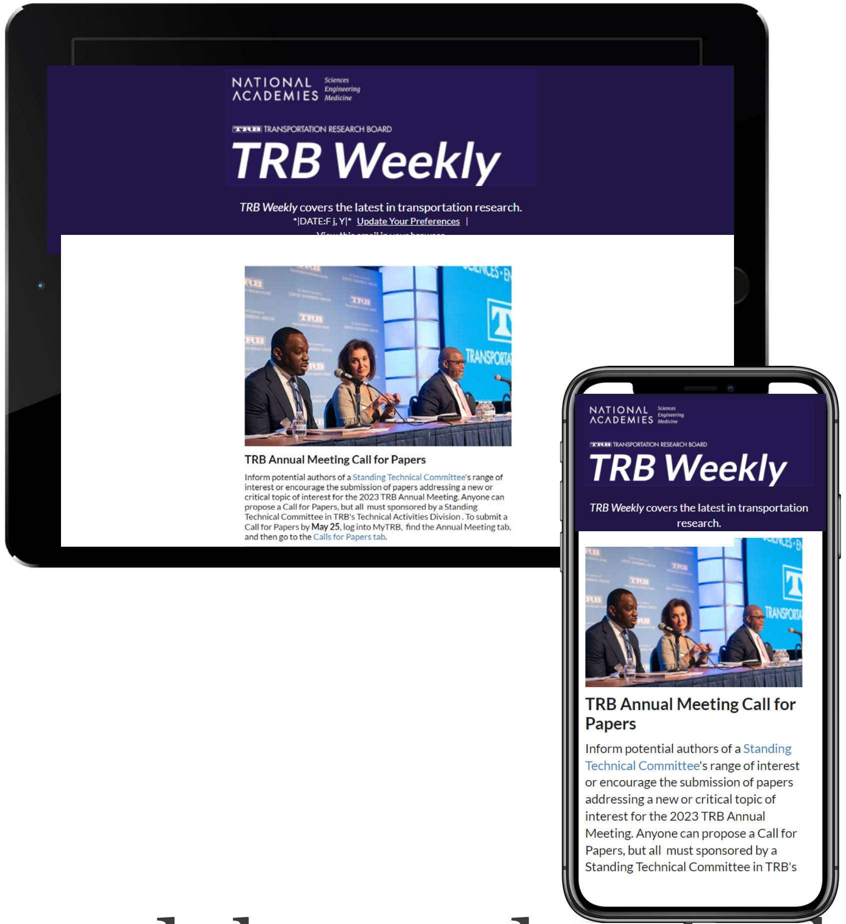

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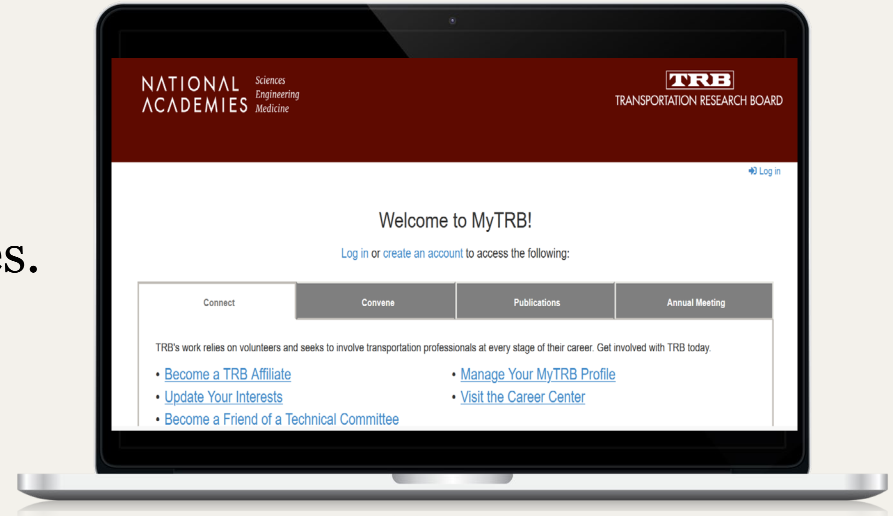

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