Defining the National Road Network

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Federal Highway Administration, Office of Highway Policy Information

U.S. Department of Transportation
Federal Highway Administration

Image: FHWA graphics library

Agenda

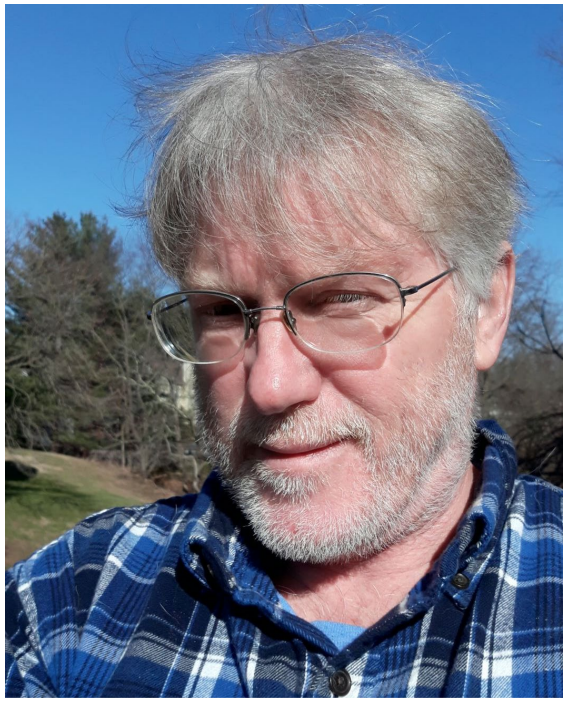
- Intros
- Part 1 – HPMS 9.0 (state level)
  - Model (Geospatial)
  - Attributes (Inventory)
  - Validations – that yield NRN
  - Role of HPMS data in the National Network
- Break (15 min)
- Part 2 – National Road Network – (national Product)
  - Background
  - Use Cases
  - Ongoing Activity/State Projects
  - Discussion

Image: FHWA graphics library

About us -

U.S. Department of Transportation
Federal Highway Administration

Tom



- HPMS v9 System Owner
- National Road Network Technical Lead
- 20 Years at FHWA
- Outside work: builds kayaks, bicycle touring, photography

Justin

- HPMS v8 System Owner
- National Road Network Project Lead
- 10 Years at FHWA
- Outside work: runs for ‘fun’, learning to play cricket, bicycle touring

Image: FHWA graphics library

Who is Attending?

Quick survey of audience groups – State DOTs, Federal, Research, Private Sector, Student, other

Image: FHWA graphics library

HPMS 9.0

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Proposed Attributes

- Functional Classification
- Facility Type
- Federal Adjusted Urban Area
- Ownership
- Route Number
- Route Name

Image: FHWA graphics library

Spatial Validations

- Geometry
- Attribute

Image: FHWA graphics library

Geometry Validations – Spikes and Kickbacks

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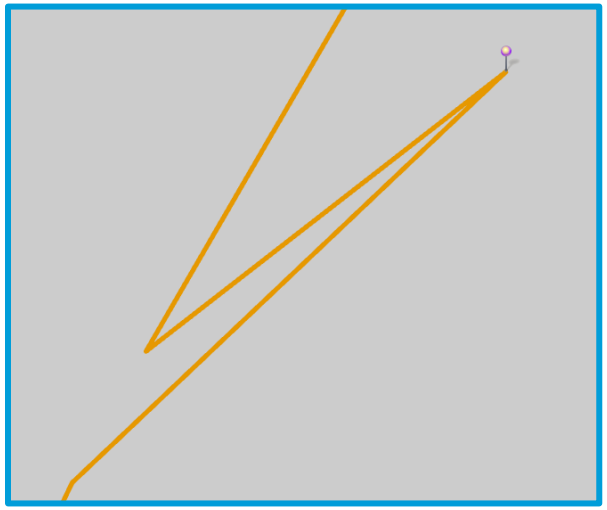
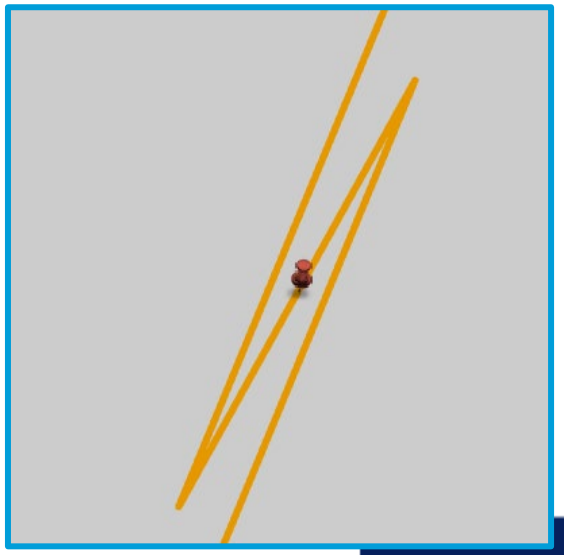
- Spike & Kickback
  - Kinks in the network
  - Occurs during digitization
  - Can be difficult to see

- Why is it an issue
  - Topology fails because centerline snaps onto itself
  - Inaccuracies in Measurement and linear length

Spike



Kickback



Geometry Validations – Duplicate Vertex

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- Duplicate Vertex

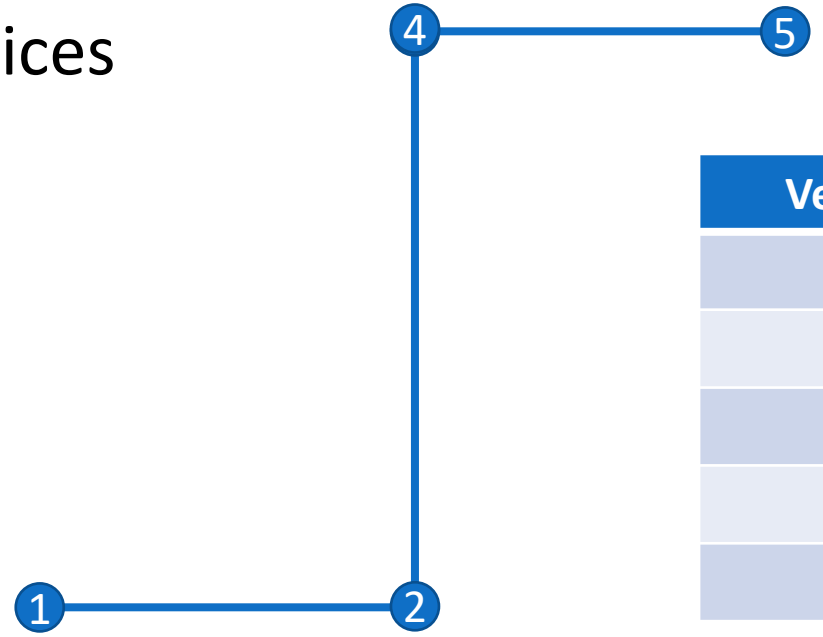
➢Consecutive coincident vertices

➢Occurs during digitization

➢Impossible to see

- Why is it an issue

1. Topology Fails



Vertex	Coordinate
1	(1 , 1)
2	(2 , 1)
3	**(2 , 2)**
4	**(2 , 2)**
5	(2 , 3)

Geometry Validations – Duplicate Feature

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- Duplicate Features

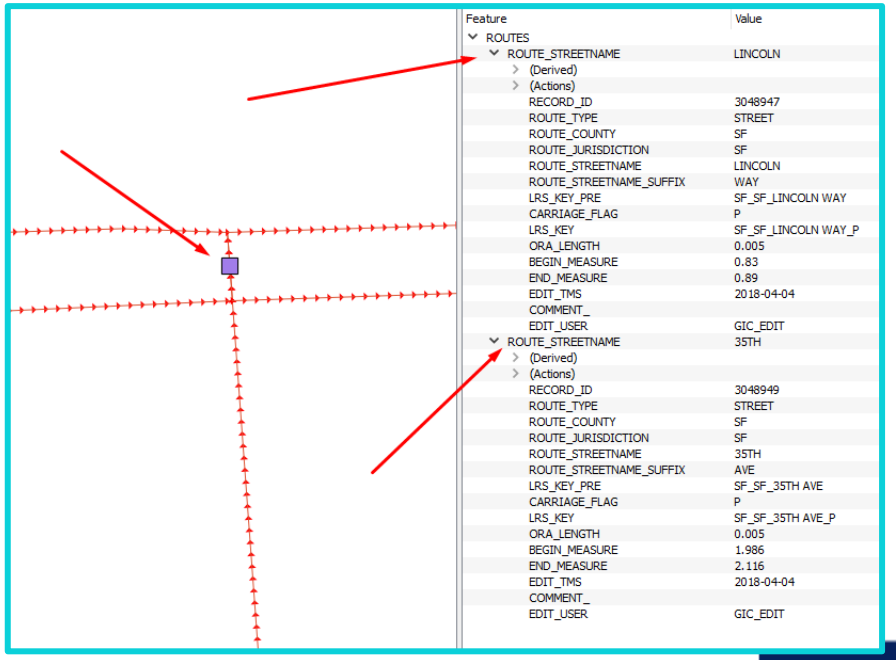
❖ Two Features (Records) with same geometry

- Why is it an issue

❖ Same Route Number
  ❖ Duplication of Data

❖ Different Route Numbers
  ❖ Double Reporting

Duplicate Features



Geometry Validations – Simple/Invalid Geometry

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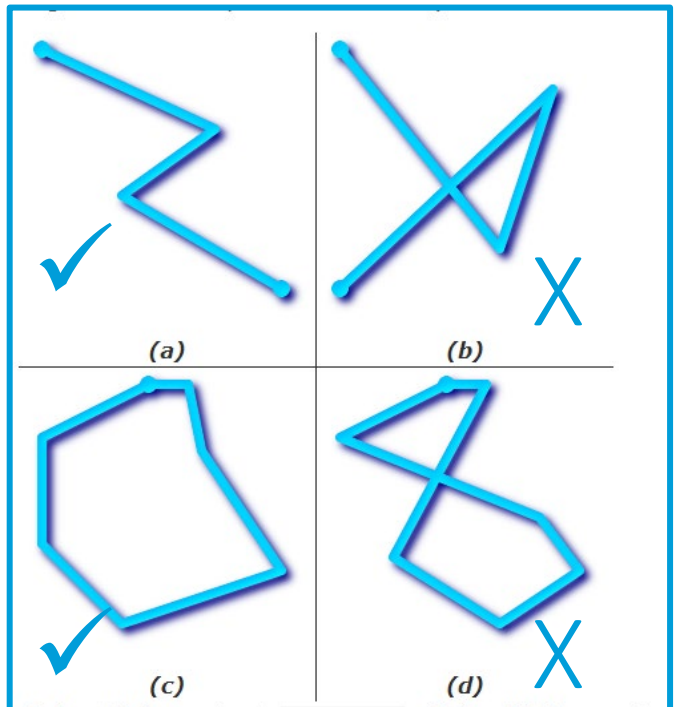
- Simple\Invalid Geometry

❖Simple: Does not cross itself

❖Valid: Has 2 or more vertexes

- Why is it an issue

❖ Not Sure, let me ask Michael



(a) and (c) are simple LINESTRINGs, (b) and (d) are not.

Geometry Validations – Overlapping Routes

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- Overlapping Routes

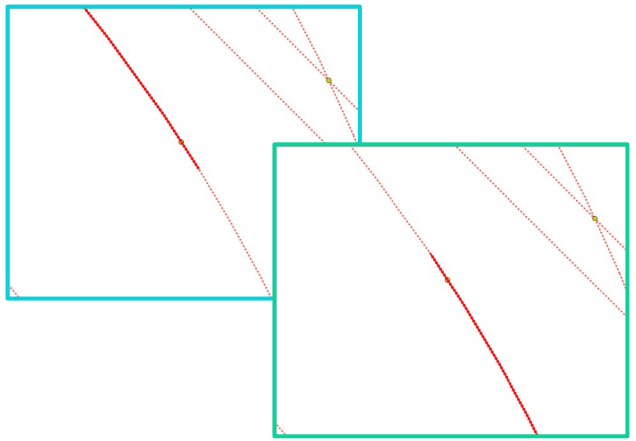
❖A Route overlaps another Route

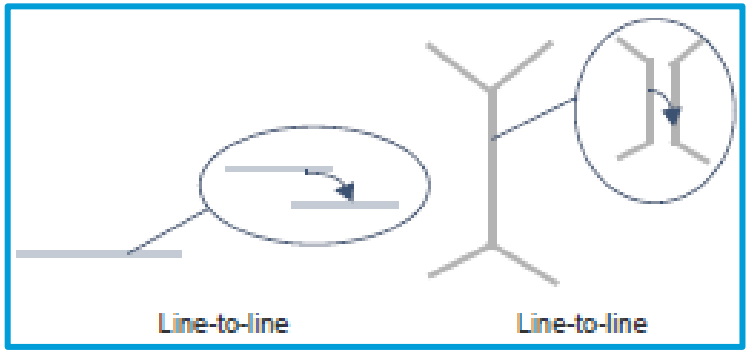
- Why is it an issue

❖Double Reporting

❖Issues performing Dynamic Segmentation

Overlaps





Geometry Validations – Linear Containment

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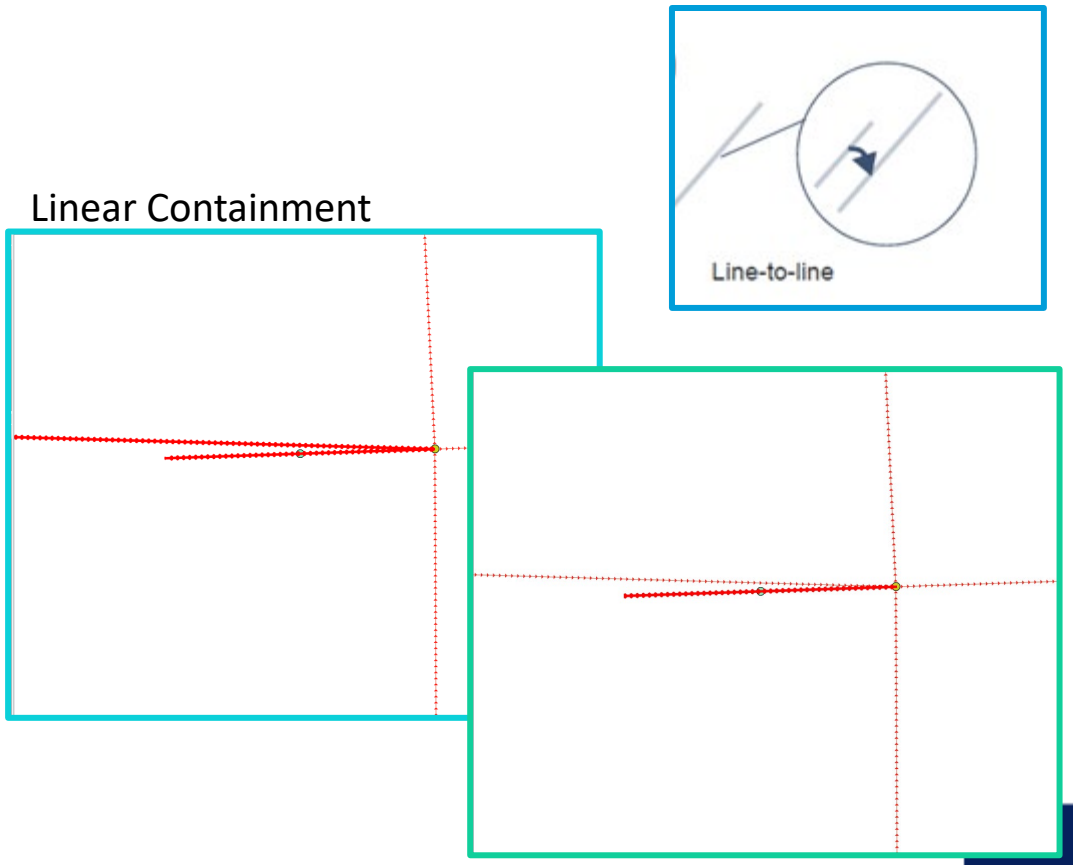
- Linear Containment
  - ❖A Route Segment is fully contained in another route
  - ❖Editor unions two geometries, doesn't delete original feature
  - ❖Found in intersections

- Why is it an issue
  - ❖Double Reporting
  - ❖Issues performing Dynamic Segmentation

Linear Containment



Geometry Validations – Self Intersection

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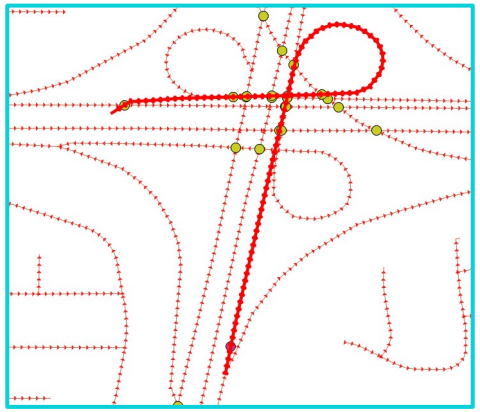
- Self-Intersections

❖A Route crosses or intersects with itself.

- Why is it an issue

❖Not sure

Self-Intersection



Geometry Validations – Over/Undershoot

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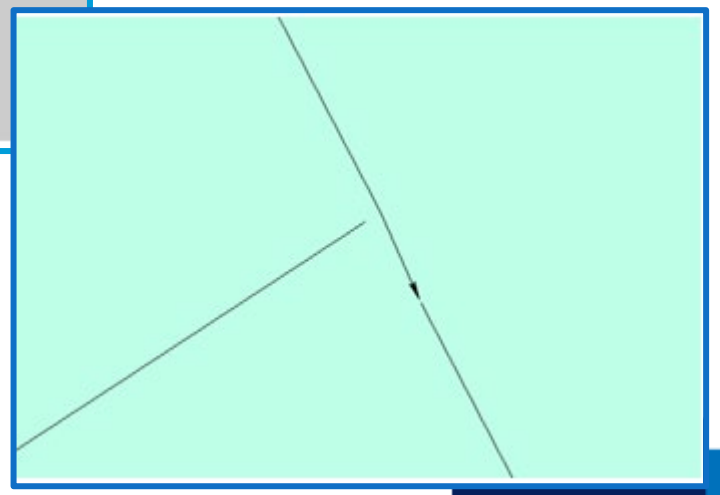
- Overshoots\Undershoots
  - ❖Routes have proper connectivity
  - ❖The start or end of a route must intersect another route if a route is within x feet.
  - ❖Aka.. Dangles

- Why is it an issue
  - ❖FHWA wants ARNOLD to be a routable connected network
  - ❖Underreporting?

Overshoot

Undershoot



Geometry Validations – Intersect Start/End

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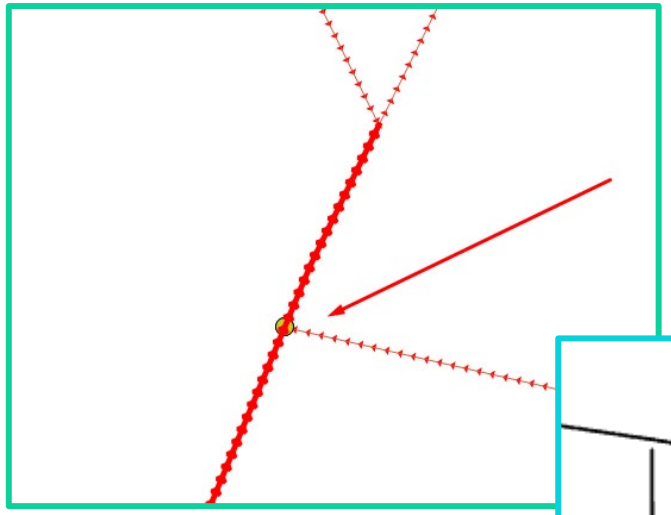
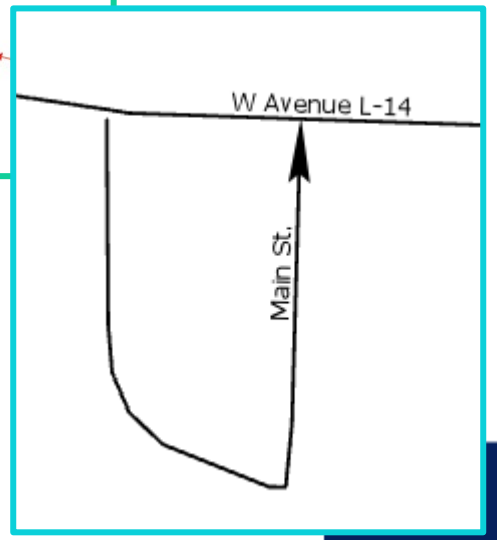
- Intersects at Start/End
  - ❖A road segment must only intersect another road at the start or end of the segment
  - ❖Should not cross over other roads
- Why is it an issue
  - ❖To be truly routable, road segments must be split at every actual intersection

Doesn't Intersect at Start\End





Geometry Validations – Bifurcations

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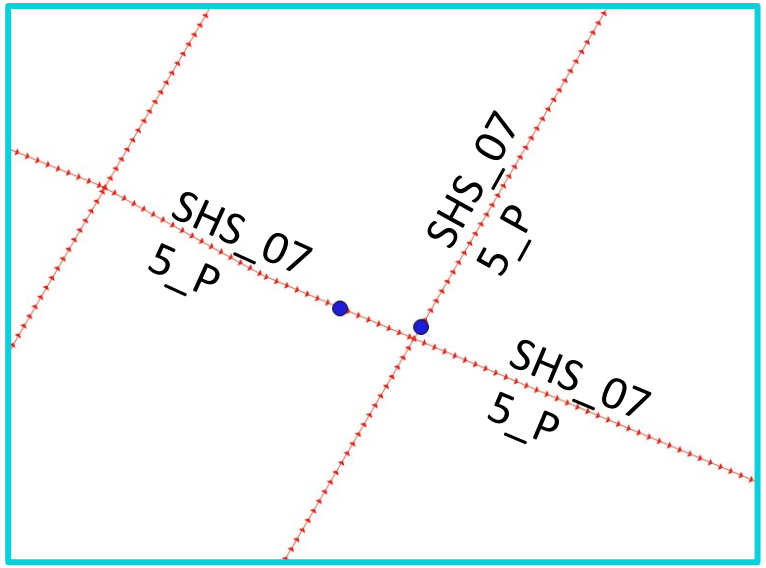
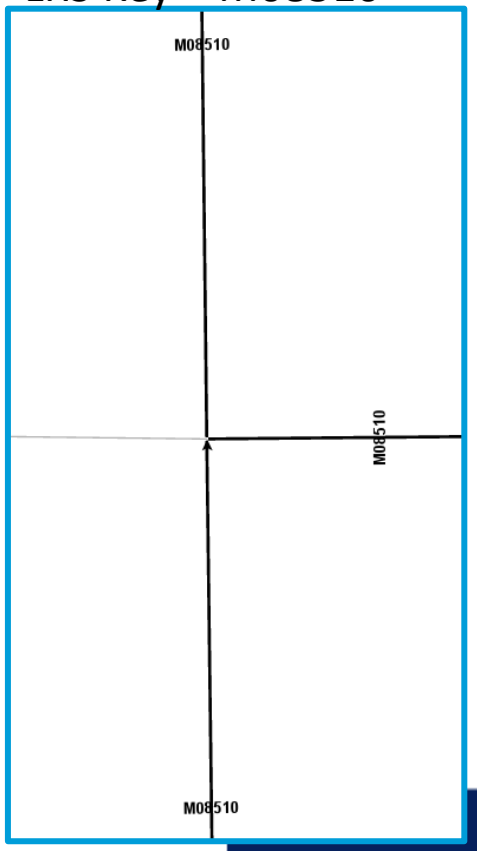
- Bifurcation
  - ❖A route intersects two other routes with same route id at the start or end
  - ❖A Forked Route
- Why is it an issue
  - ❖LRS Issues: Which measure values do you follow?
  - ❖Dynamic Segmentation Problems

Bifurcation – LRS Key = SHS_075_P



LRS Key = M08510



Project Description

Last year, FHWA began a project to link the Interstate System across State Boundaries.

Goal: This was an effort to prove a concept that can be applied to All Roads and have a real product at the end.

Image: FHWA graphics library

Methodology Step 1 and 2

Establish Snap Points (Points of Demarcation, Snap to Points etc.)

- These would be located on a State Boundary using Census defined Boundaries.
- The points are calculated as the mid-point between the extension of each State's geometry.
- Automate the Geometry to 'Snap To' the point.

Image: FHWA graphics library

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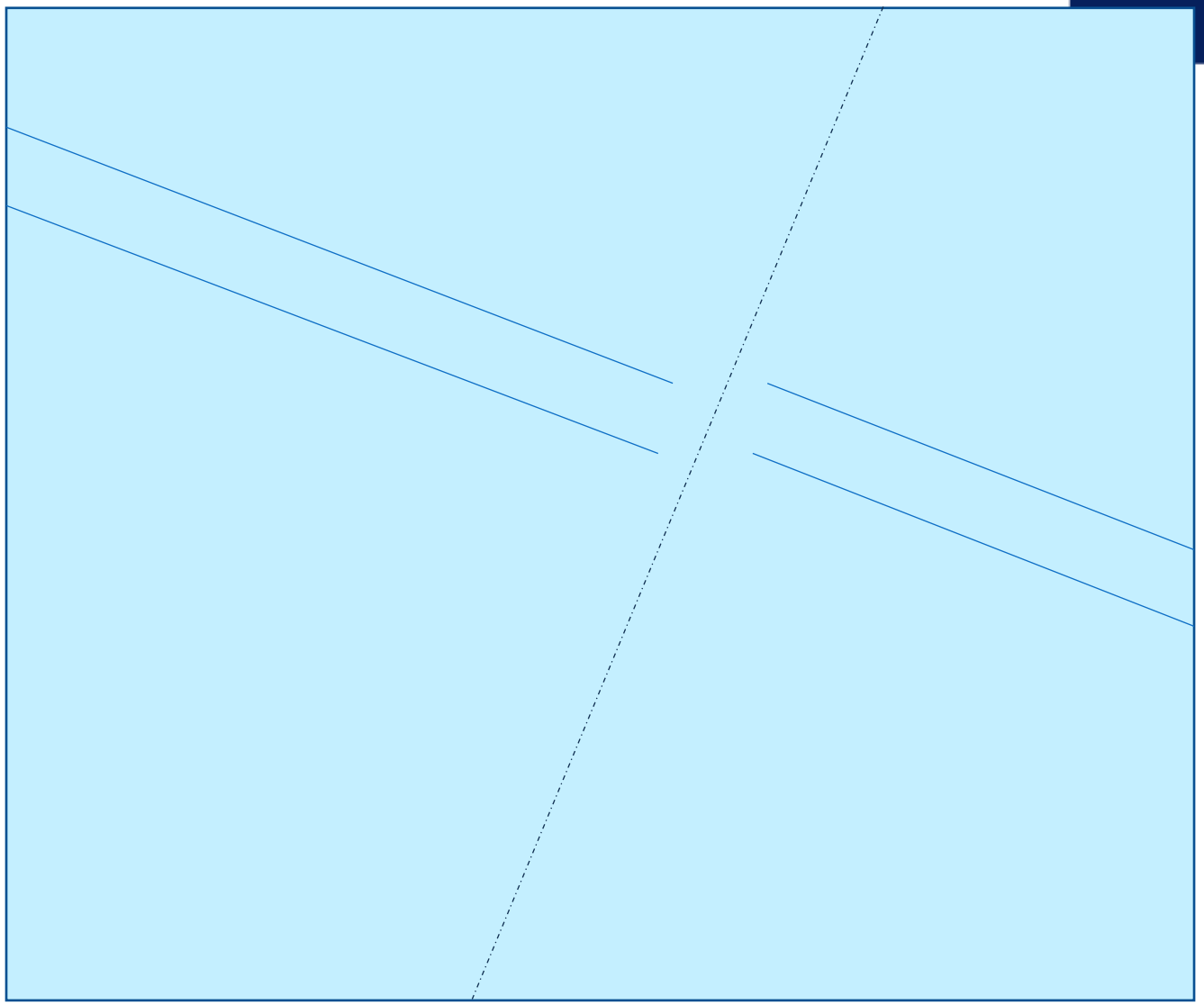
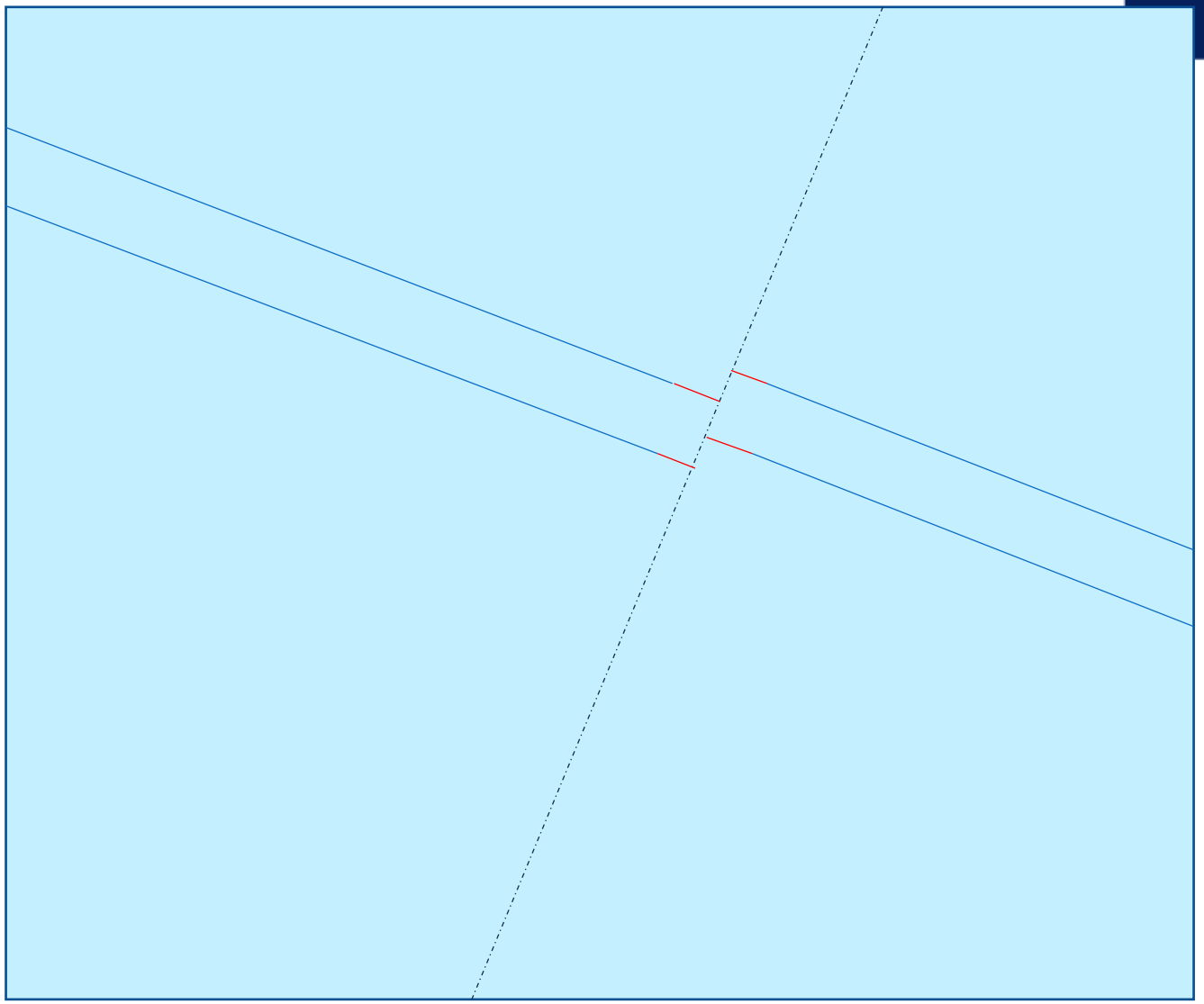
Example Step 1



Example Step 1



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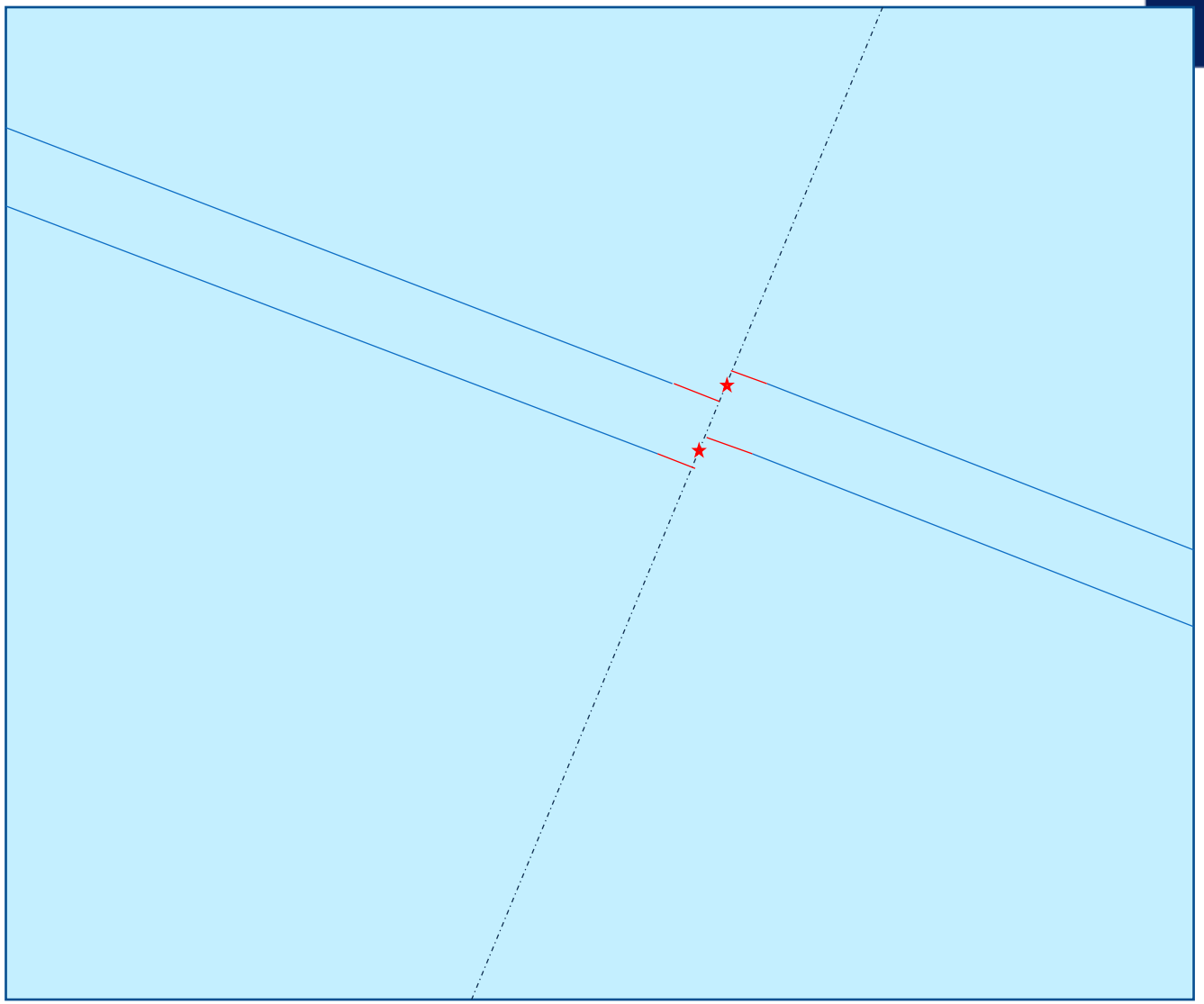
Example
Step 1



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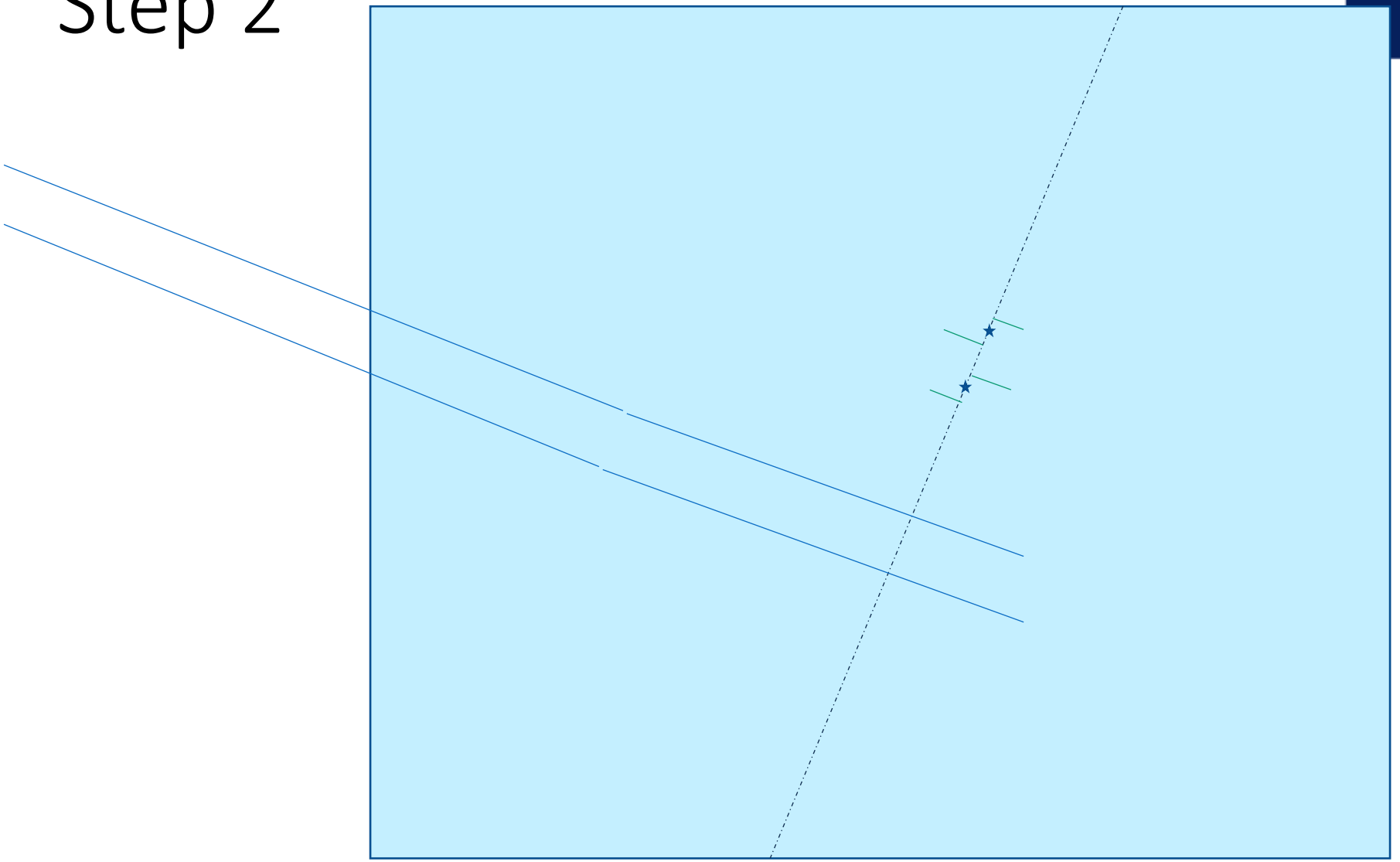
Example
Step 2



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Methodology Step 3

States working with their neighbor can move the Snap Point through an MOU.

FHWA intends to facilitate this process

If an agreement can not be met. See Step 1.

Image: FHWA graphics library

Implementation

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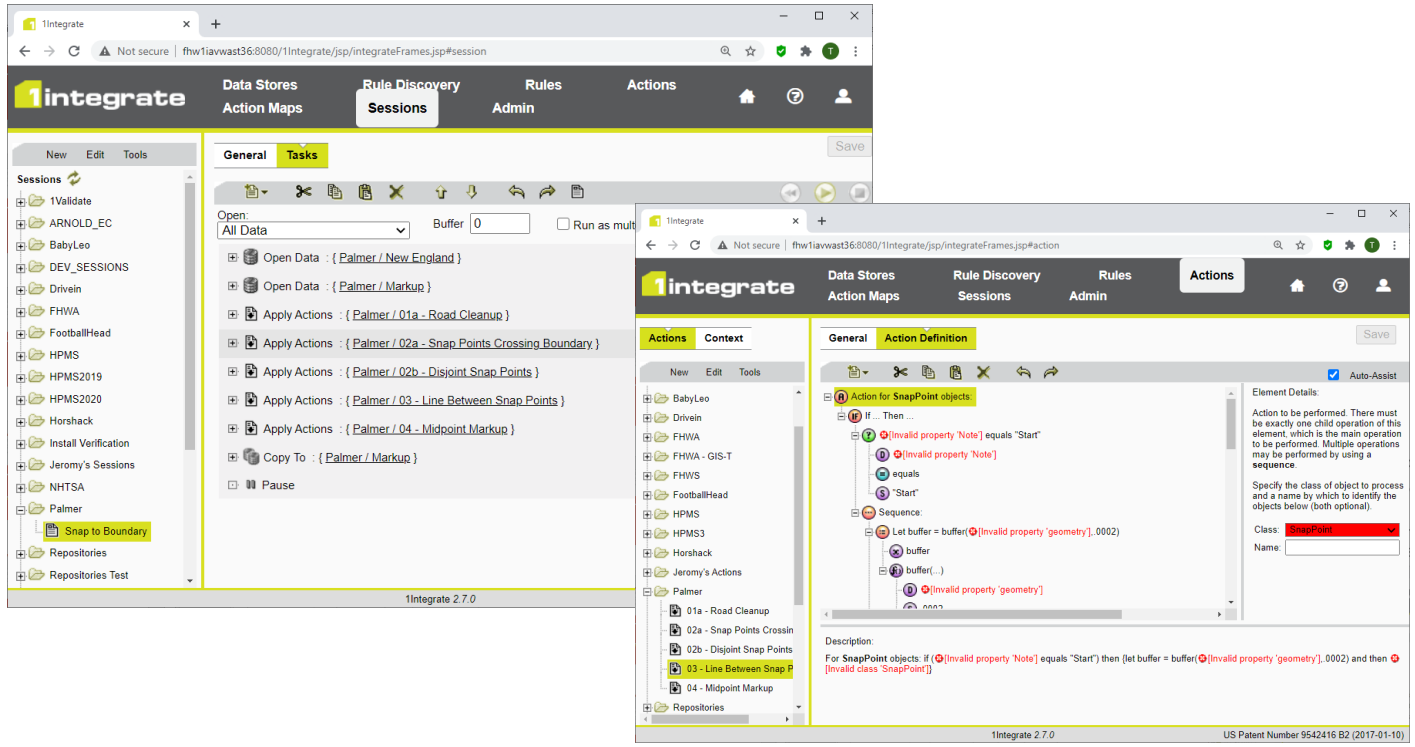
Rules were written in 1Integrate (1Spatial) with about 85% connectivity in the first attempt.

The rules had trouble crossing over State Boundaries that referenced the shoreline.

We switched out the Census State Boundary file and replaced it with the Census County File.



Challenges

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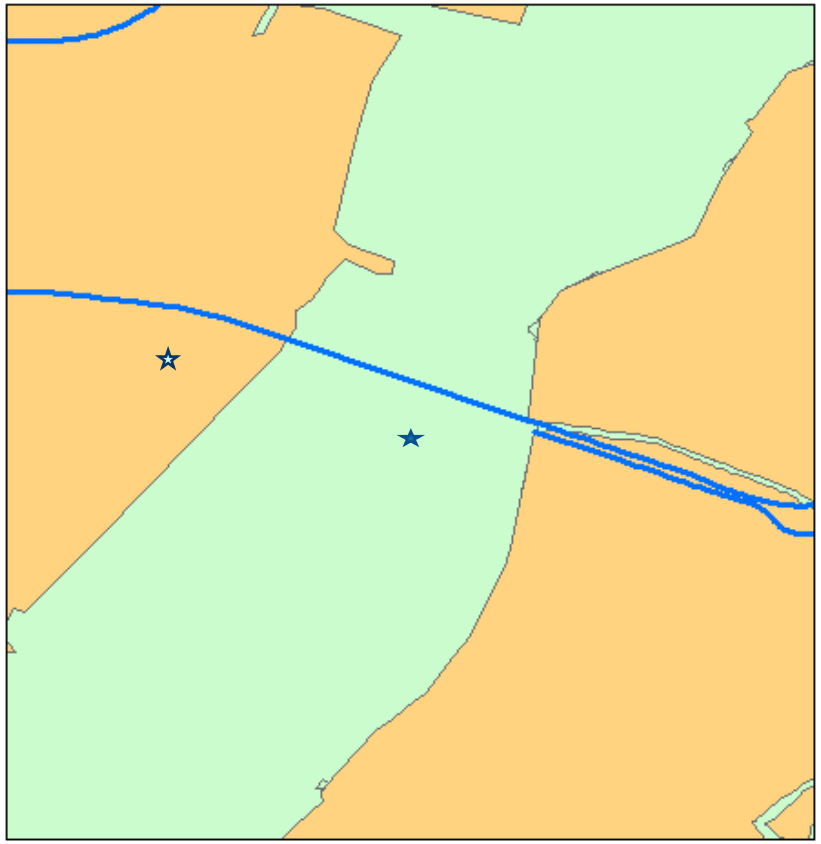
The rules had trouble crossing over State Boundaries that referenced the shoreline.

We switched out the Census State Boundary file and replaced it with the Census County File.



Next Steps

- Develop this type of process into the National Road Network
- Expand the process beyond the Interstate System

Image: FHWA graphics library

Image: FHWA graphics library

The National Road Network (Pilot)

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Background

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- In 2019, Congress appropriated funds for FHWA to create a National Road Network using data reported to HPMS by State DOTs.
- Three network focus areas:
  - Connectivity
  - Representation
  - Spatial Accuracy
- The resulting network should also:
  - Support Interagency use
  - Enhance timeliness of data

National Road Network Pilot (NRNP)

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Federal Highway Administration

- Phase I (Pre-Process Support)
  - Leverage grant funding to pilot group of states
  - States develop projects to test and implement network improvements
    - Connectivity
    - Representation
    - Accuracy
- Phase II (Post-Process Support)
  - Produce a national spatial file addressing the stated issues
  - Develop repeatable process for national network development
- Contract Support

Project Schedule

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Federal Highway Administration

	2020	2021										
	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	*Continued Through Sept 2022*
US DOT Expert Panel												
Pilot DOT Workshops												
Pilot DOT Meetings												
National State DOT Webinars												
Final Report + Presentation												
Collab with Pilot State DOTs												
GIS-T Workshop												

2020 Update

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Federal Highway Administration

- Second appropriation in 2020 expanded project goals.
  - Data standard for geospatial data
  - Data interoperability, reuse, integration
  - Data sharing
- Additional project phases will be added to support these goals

Why Now?

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NRNP Opportunities

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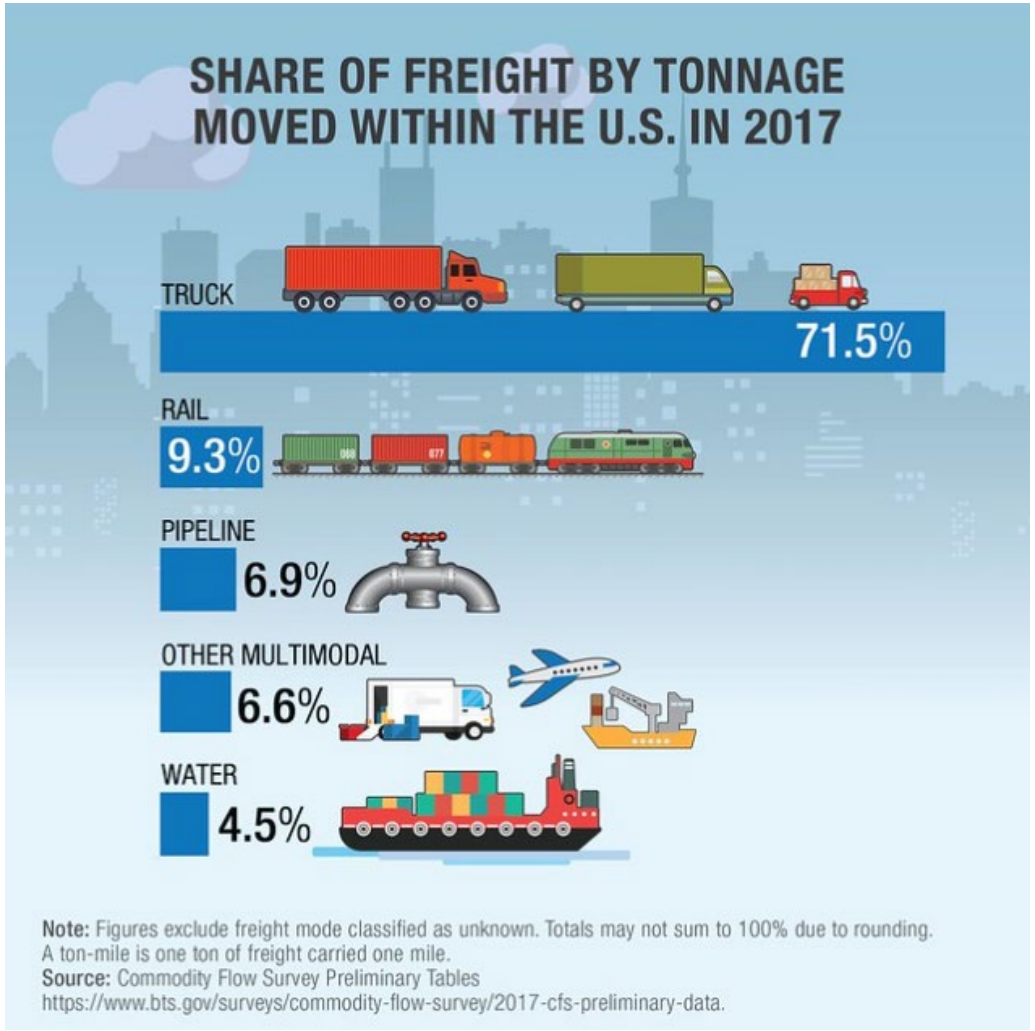
- Challenges with direct application of ARNOLD
  - Routing
  - Connectivity (inter and intra state)
  - Intersections
  - Inventory/non-inventory data
- Growing Need for Consistent National Network
  - Freight
  - Safety
  - Emergency Response
  - Planning

Disconnected routes at the border of adjacent states

Map: Federal Highway Administration

Use Case – Freight



Source: Federal Highway Administration

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ARNOLD → FAF Challenges

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- Network Limitations
  - Center line representation for Interstates/Freeways/Expressways and ramp connections
  - Grade separation of bridges/overpass not represented
  - Inconsistency in network coding
- Process Challenges
  - Large gap in current HPMS GIS data for development a model network
  - Limited use for planning and analysis
  - Difficult to perform trend analysis (stability of network)
  - Resource intensive repeat update

HPMS vs. FAF Linework

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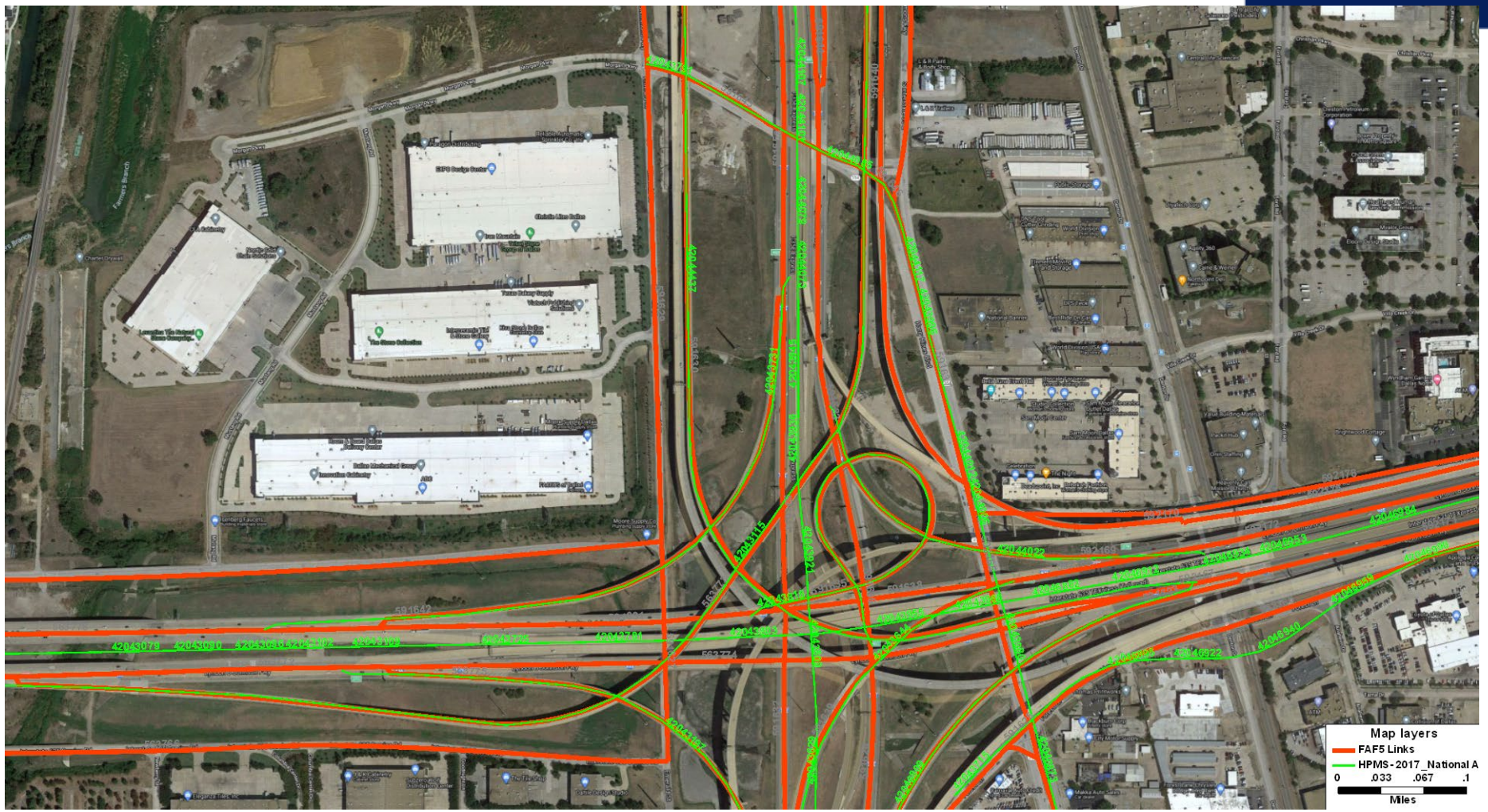

Image: Freight Analysis Framework – Federal Highway Administration

Project Focus Areas

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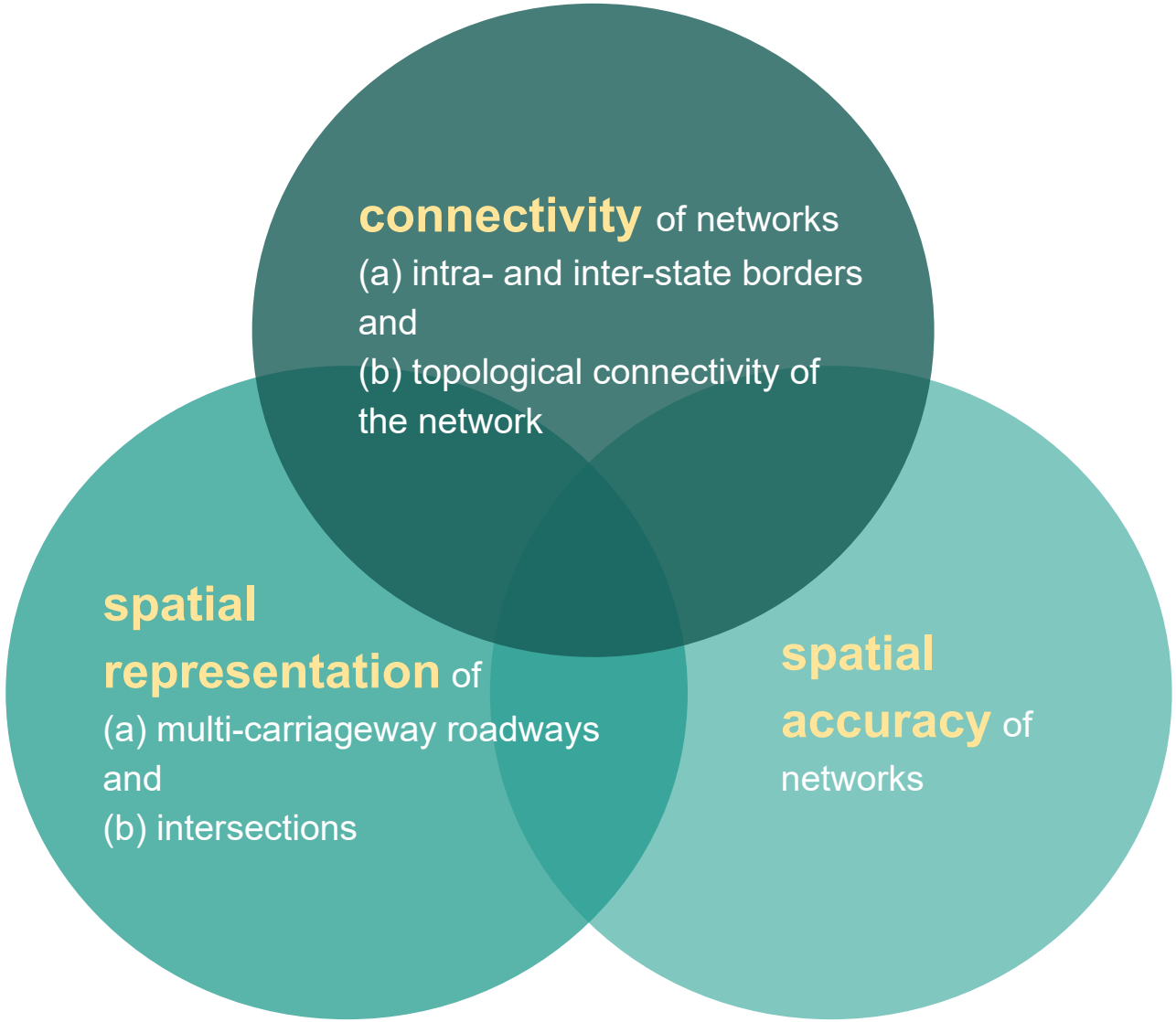

FHWA/US DOT Use Cases of NRN

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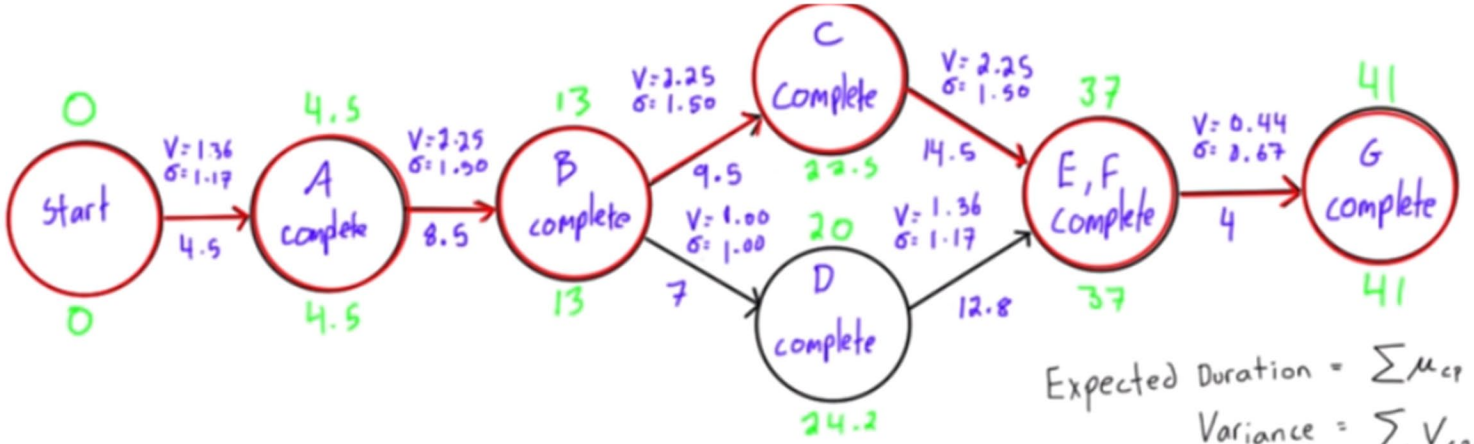
Use Cases	Network Connectivity	Spatial Representation	Spatial Accuracy
Emergency Response (e.g., Road Closure Tracking)	X	X	X
Safety Analysis		X	
Crash Analysis		X	X
Freight Analysis	X		
Highway Project Locations		X	X
Geospatial Analysis of National Datasets (e.g., Traffic Modeling, NBI)	X	X	X

Note – the NRN will support analysis. It is NOT operational.

Progress to Date



Expected Duration = $\sum \mu_{cp} = 41$

Variance = $\sum V_{cp} = 8.55$

Standard Deviation = $\sqrt{\sum V_{cp}} = 2.92$

$$Z = \frac{X - \mu}{\sigma}$$

Z = Z score

x = # days in question

μ = expected duration

σ = standard deviation

Source: www.engineer4free.com

Outreach and Engagement

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- Symposium: September 16-17, 2021
  - Private sector, research community, US DOT stakeholders
- State Workshop: January 27, 2021
  - State DOTs in project focus area
- Expert Panel: December 2020, February 2021, bimonthly
  - FHWA and US DOT stakeholders
- Other State and National Outreach
  - GIS-T, webinars

Symposium Feedback

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- 50 states - 50 stories
- Reliability, sustainability,
  repeatability of supply chain
- Design for all impossible
- Clearly communicate data model (metadata)
- Coordination with networks like Next Gen 911
- Connectivity between states won’t solve everything but has big benefits

State Workshop Feedback (Connectivity)

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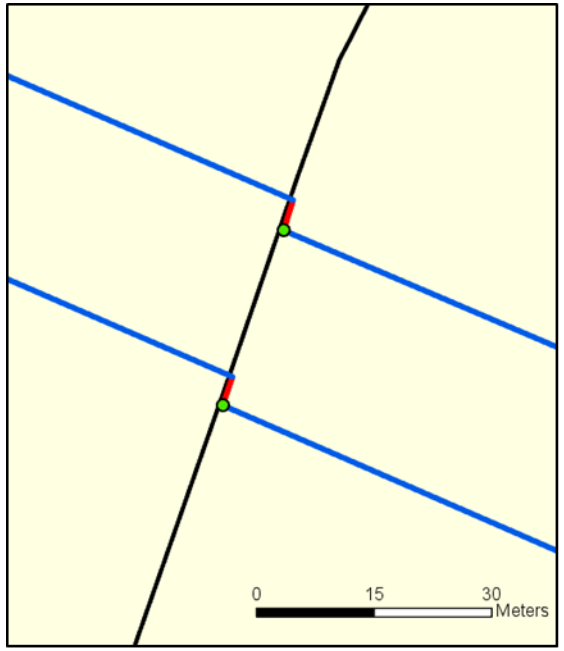
- Authoritative match-point data needed at borders
  - a.k.a alignment points, snap-to-point, etc.
  - Require governance, coordination & collaboration across jurisdictions and programs
- Complicating factors include:
  - Multiple types of match-points: mileage certification, geometric, jurisdiction, and maintenance, etc.
  - Political boundary disagreements
  - Data model and spatial accuracy differences at the boundary (e.g., one jurisdiction represents a road as multi-carriageways, but the other doesn't)



Source: FHWA, ARN

State Workshop Feedback (Network Topology)

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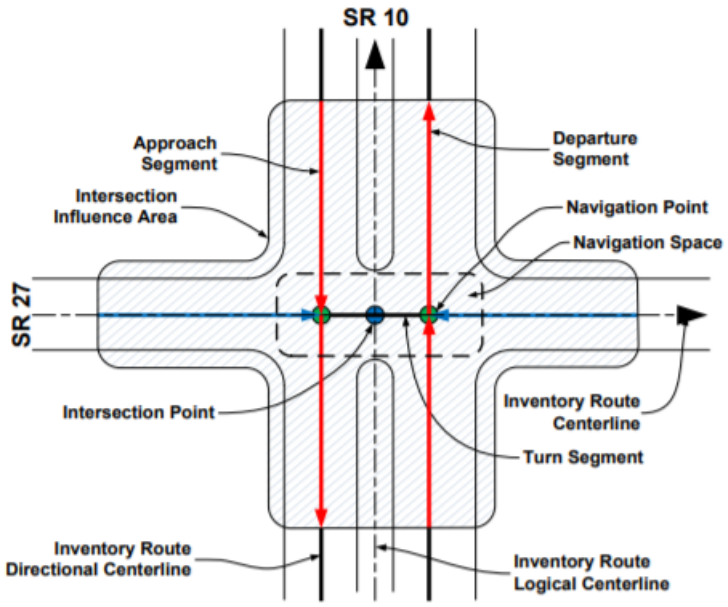
- The majority of State DOTs have topological connectivity across the network
- Data maintenance variations complicate maintenance of a connected network
- Different data modeling approaches exist at State and Local levels (e.g., multi-carriageways, traffic circles, and intersections)
- Intersection Points are key for ensuring network topology



Source: AEGIST Guidebook
https://www.gis.fhwa.dot.gov/documents/AEGIST_Guidebook.pdf

State Workshop Feedback
(Spatial Representation of Multi-Carriageways)

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- Most DOTS have multi-carriageway geometry
- There is a mix of attribute maintenance approaches
  - Just maintained on the inventory side
  - Some maintain on both, but only report on the inventory side
- NRN is only looking for key attributes on both sides
  - Functional class
  - Facility type
  - Route ID

Single-Centerline vs. Dual-Carriageway representation - ARNOLD

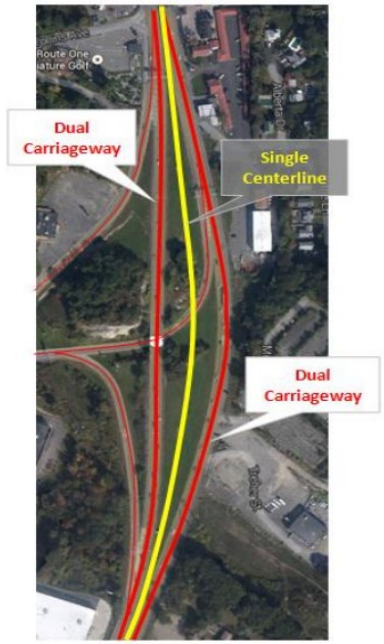

Image: ARNOLD Reference Manual, Michael Baker Jr., Inc., 2014

Expert Panel Feedback

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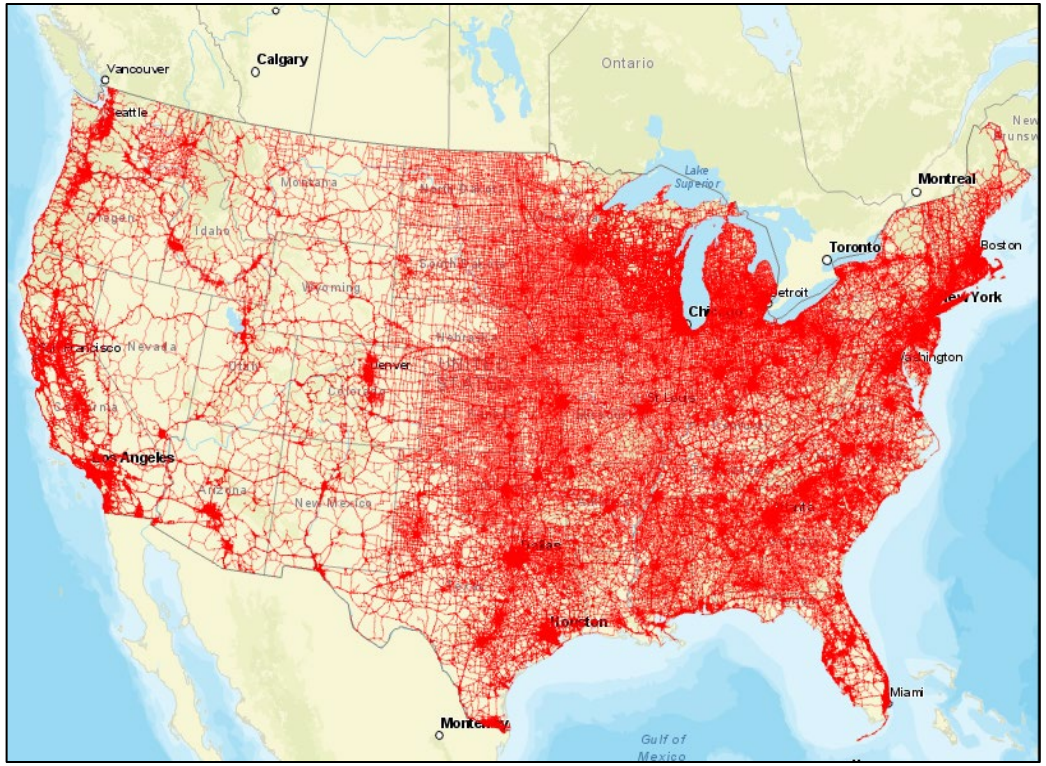
- Coordination of national products networks is key
- Stakeholders are ready for connected/improved network yesterday, e.g. FAF, ARN
- Use cases and coordination opportunities across US DOT – Planning, AEGIST, NHTSA, MIRE



Source: FHWA, ARN

Ongoing Tasks

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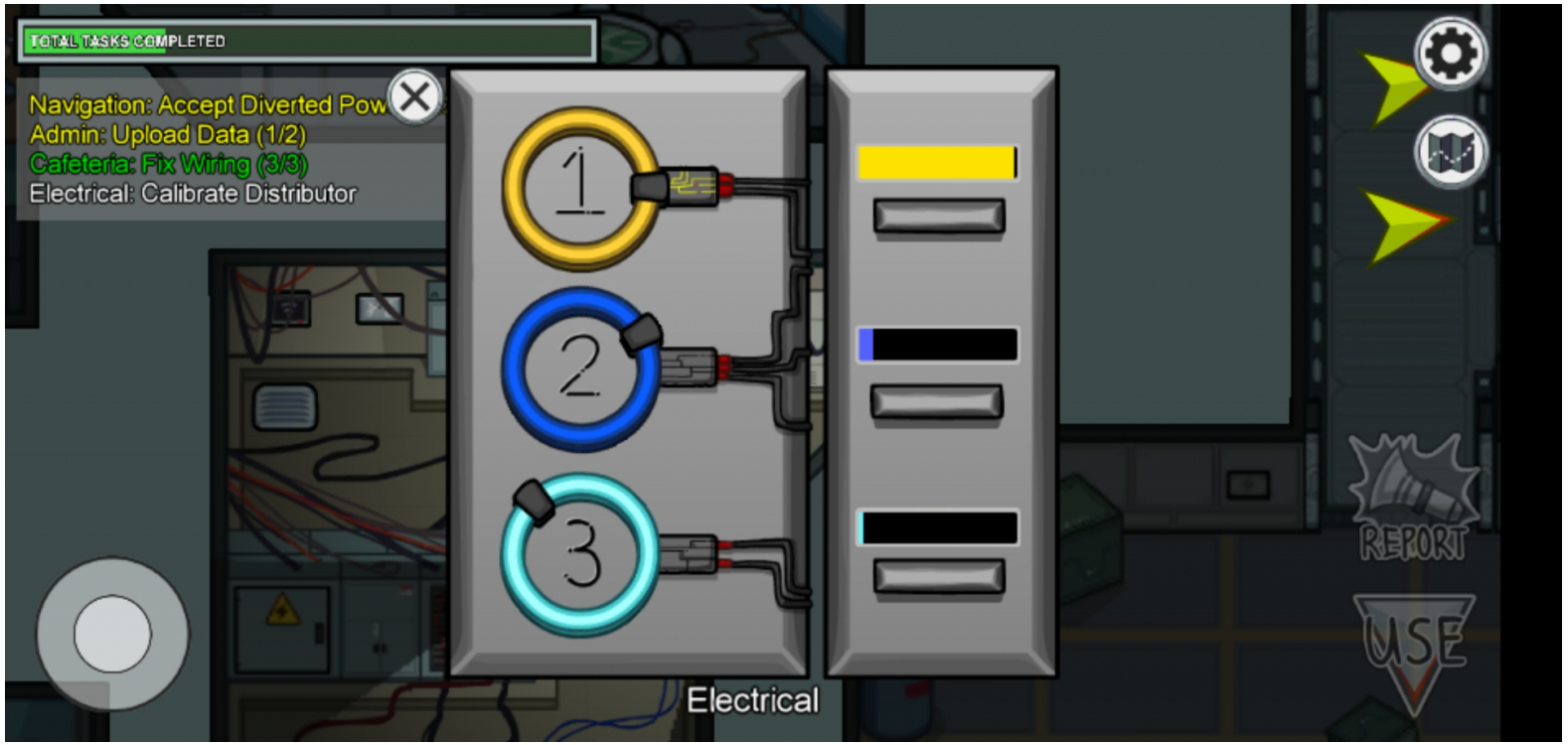

Source: https://gamewith.net/among-us-wiki/article/show/22106

Current Pilot Focus States

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Map: Federal Highway Administration

Alabama

Delaware

District of Columbia

Florida

Georgia

Maryland

Mississippi

North Carolina

South Carolina

Virginia

What Are We Asking For?

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Network Connectivity	Inter-State Borders	• On-System Roads connect at boundaries of abutting States at match points agreed upon by the states and accepted by FHWA
	Intra-State Borders	• On-System Roads between abutting jurisdictions within the State (Counties, Federal Lands, Sovereign Nations, etc.) are connected at agreed-upon match points
	Topological connectivity of the network	• Intersection points are present at route intersections and segments connections on ALL roads • Roads maintained by different jurisdictions within the state are present in the state's roadway network • Roadway network data is topologically correct (absent of gaps, overlaps, slivers)
Spatial Representation	Multi-Carriageway Roadways	• Multi-Carriageways are represented as multiple lines • Attribution exists on both sides of the roadway for key attributes (functional class, facility type, route ID)
	Intersections	• Implement the AEGIST hashtag intersection model, maintaining a single point at each intersection location.
Spatial Accuracy	**Spatial Accuracy Standards**	• Align with AEGIST horizontal spatial accuracy spec of +/- 14ft • Include metadata to clarify spatial accuracy and data collection method differences across the network (e.g., for on vs off-system roads)

Example State Project Goals

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DC

- Dual Carriageway Representation - Attribute assignment on multi-lines
- Inter-state Connectivity - Dual carriageway alignment with abutting states

Delaware

- Intra-state Connectivity - Coordination with non-DOT data owners (e.g., National Seashore State Park, U.S. Army Corps of Engineers Chesapeake & Delaware Canal)

North Carolina

- Inter-State Connectivity
- Improve location of match points
- Build upon previous work with South Carolina and explore connectivity with Virginia

Maryland

- Inter- and Intra-State connectivity cleanup
- Improve attribution for inventory and non-inventory directions

Project Schedule

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Federal Highway Administration

	2020	2021										
	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	*Continued Through Sept 2022*
US DOT Expert Panel												
Pilot DOT Workshops												
Pilot DOT Meetings												
National State DOT Webinars												
Final Report + Presentation												
Collab with Pilot State DOTs												
GIS-T Workshop												

NRN Context

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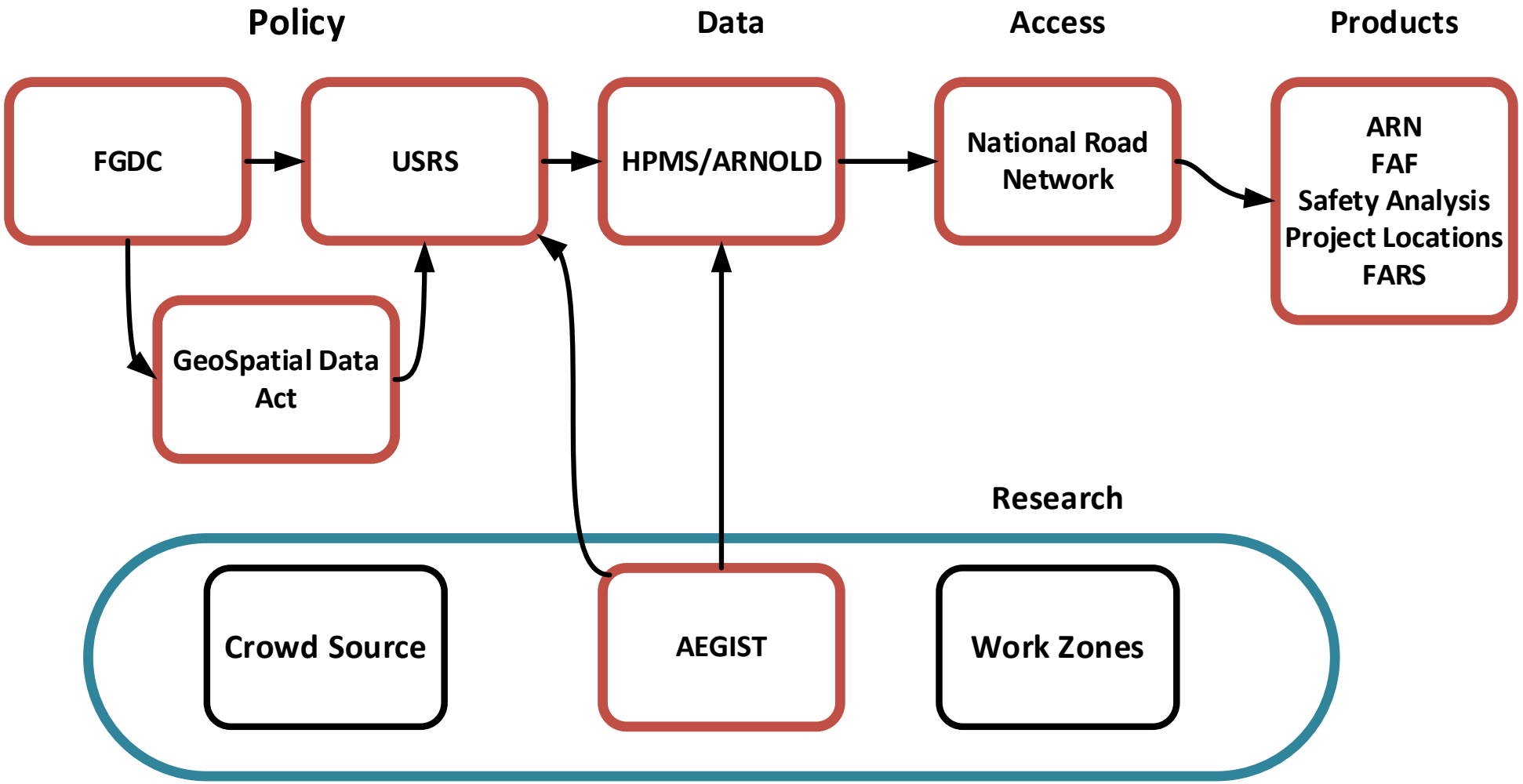

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Discussion

National Road Network Pilot Questions

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- Spatial Representation
  - Do you have data on non-inventory directions?
- Connectivity
  - Have you established connection points with neighboring states?
    - What linework changes would you have to make to meet FHWA points?
  - Are internal network connections complete?
    - E.g. federal data including Park Service, Forest Service, etc.
- Spatial Accuracy
  - What are states doing now, how could/would this change for NRN?

National Road Network Questions

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- FHWA just produced this product, is it going to help me?
  - State DOT
  - Research Community
  - Private
  - Other
- Access to network – how do we get a copy?
  - What is available now?
  - What format do you need?
  - How would you like to access this? Web feature service, portal, etc.

HPMS Data and the National Road Network

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- Policies
  - Data Sources
    - HPMS
    - Other federal data
    - Third party, non HPMS data – how does this fit?
    - Conflation?
  - Manipulation of data
    - Border linework
- Is this just HPMS or is there other value added in the NRNP

Contact Information

U.S. Department of Transportation
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- National Road Network Pilot website: https://data.transportation.gov/nationalroadpilot

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