

System Operations, Airspace & Aeronautical Information Management

Implementing
Electronic Terrain and Obstacle Data
(eTOD)
In the United States



Federal Aviation
Administration



Competition for the Sky

What is eTOD?

The International Civil Aviation Organization (ICAO) calls for sets of terrain and obstacle data which when used in combination with aeronautical data can support various air navigation applications and planning procedures

ETOD is designed to support

- Onboard Ground Proximity Warning Systems
- Minimum Safe Altitude Warning System
- One Engine Inoperative Contingency Planning
- Aircraft Operating Limitation Analysis
- Instrument Approach and Departure Procedure Design
- Determination of En-Route Drift-Down Procedure

ETOD is designed to support

- En-Route Emergency Landing Locations
- Advanced Surface Movement Guidance and Control Systems
- Aeronautical Chart Production and Flight Simulators
- On-Board Databases
- Synthetic Vision
- Obstacle Restriction and Removal



ETOD Requirements

ETOD subdivides the “State” into four distinct areas with specific vertical and horizontal accuracy requirements for each area

- Area 1 – Entire Territory
- Area 2 – Terminal Control Area
- Area 3 - Airport/Heliport Movement Areas
- Area 4 – Category II and III Operations Area

Area 1

Obstacle Requirements

- Above Ground Level – 100 meters
- Vertical Accuracy – 30 meters
- Vertical Resolution – 1 meter
- Horizontal Accuracy – 50 meters
- Confidence Level – 90%
- Data Classification-routine
- Integrity Level – 1×10^{-3}
- Maintenance Period – as required

Does the US Meet Area 1 Obstacle Requirements?

Legally, Yes

- ICAO calls for the collection of obstacles 100 meters (300 feet) or taller.
- 14 CFR Part 77.13 requires the reporting of all obstacles greater than 200 feet to the FAA. ***Technically*** an analysis of existing data should be performed to determine if our data meets the eTOD accuracies. Our confidence is high due to amount of resources we expend to verify obstacles greater than 200 feet.



Area 1

Terrain Requirements

- Post Spacing – 3 arc seconds (approx 90 meters)
- Vertical Accuracy – 30 meters
- Vertical Resolution – 1 meter
- Horizontal Accuracy – 50 meters
- Confidence Level – 90%
- Data Classification-routine
- Integrity Level – 1×10^{-3}
- Maintenance Period – as required

Does the US Meet Area 1 Terrain Requirements?

Yes

Shuttle Radar Topography Mission (SRTM) and the USGS National Elevation Data (NED) Set

- SRTM data was collected with data points spaced every 1 arc second (approx 30 meters). Horizontal accuracy of 20 meters and vertical accuracy of 16 meters.
- NED data is collected at 1 arc second (approx 30 meters) resolution with a horizontal accuracy equal to the 7.5' topographic map series and vertical accuracy of +/- 7 to 15 meters.



SRTM Generated Image



Only One Problem

How much “Area 1” actually exists in the United States as defined by the ETOD requirements? When we examine the requirements for Area 2, we find only a portion of the United States can be considered “Area 1” by our own legal descriptions of terminal airspace according to Order 7400.9

ICAO Definition of a Terminal Control Area (TCA)

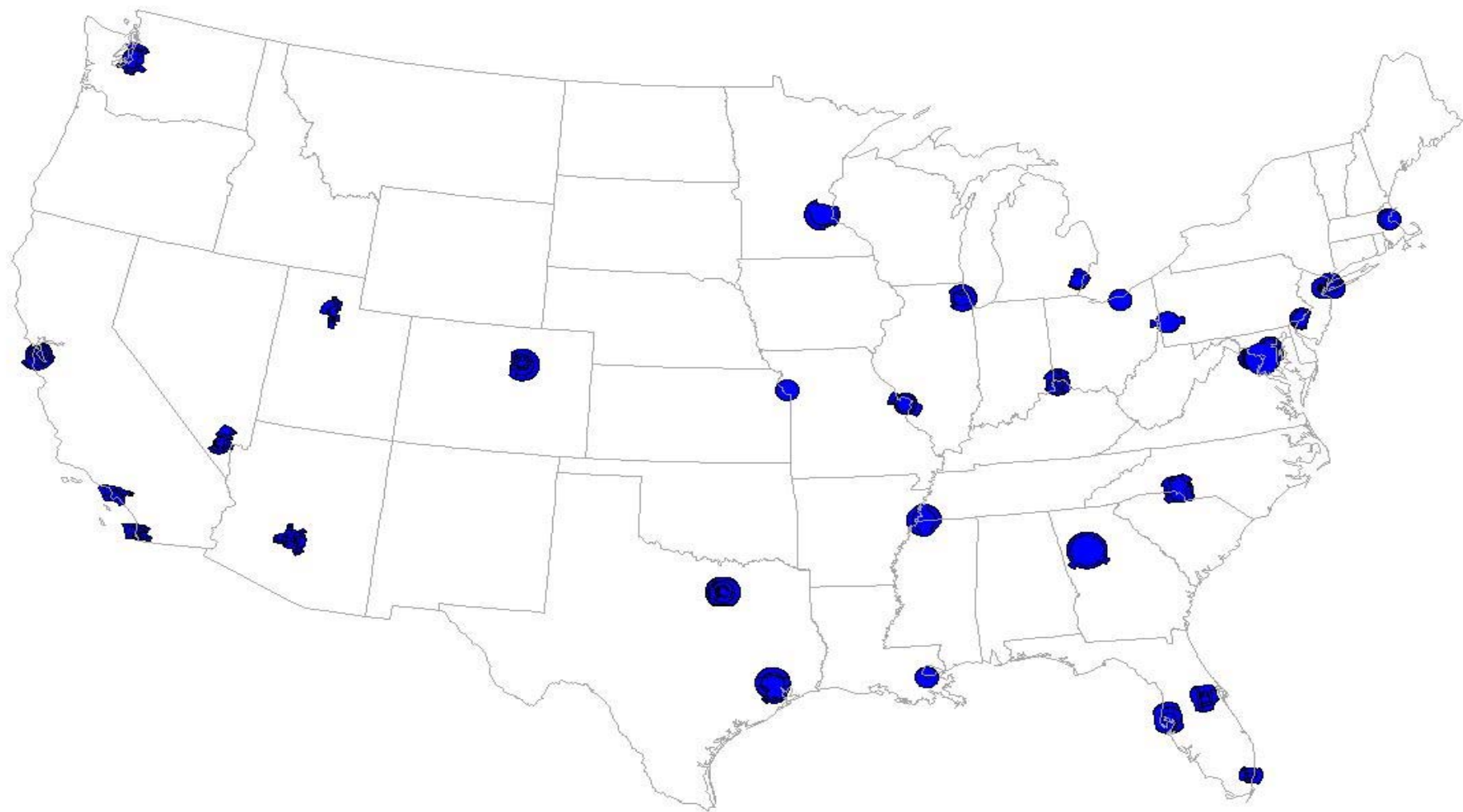
- The smaller of the TCA or 45 km radius of an airport
- No TCA at an airport with IFR Ops, 45 km radius

7400.9 Defines Terminal Airspace

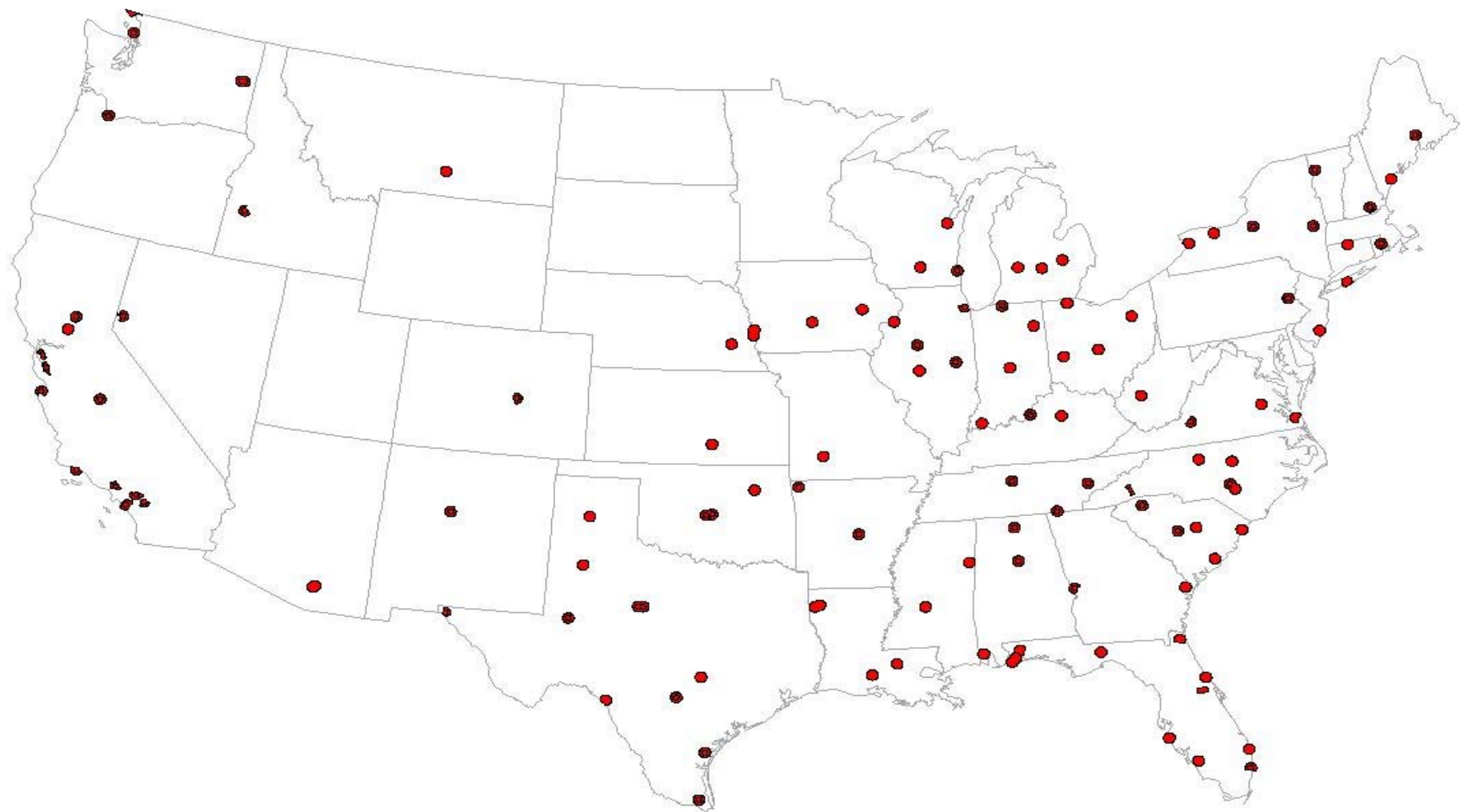
- Class B Airspace
- Class C Airspace
- Class D Airspace
- Class E Surface Airspace
- Class E 700' Floor Airspace
- Class E Other Than 700' Floor



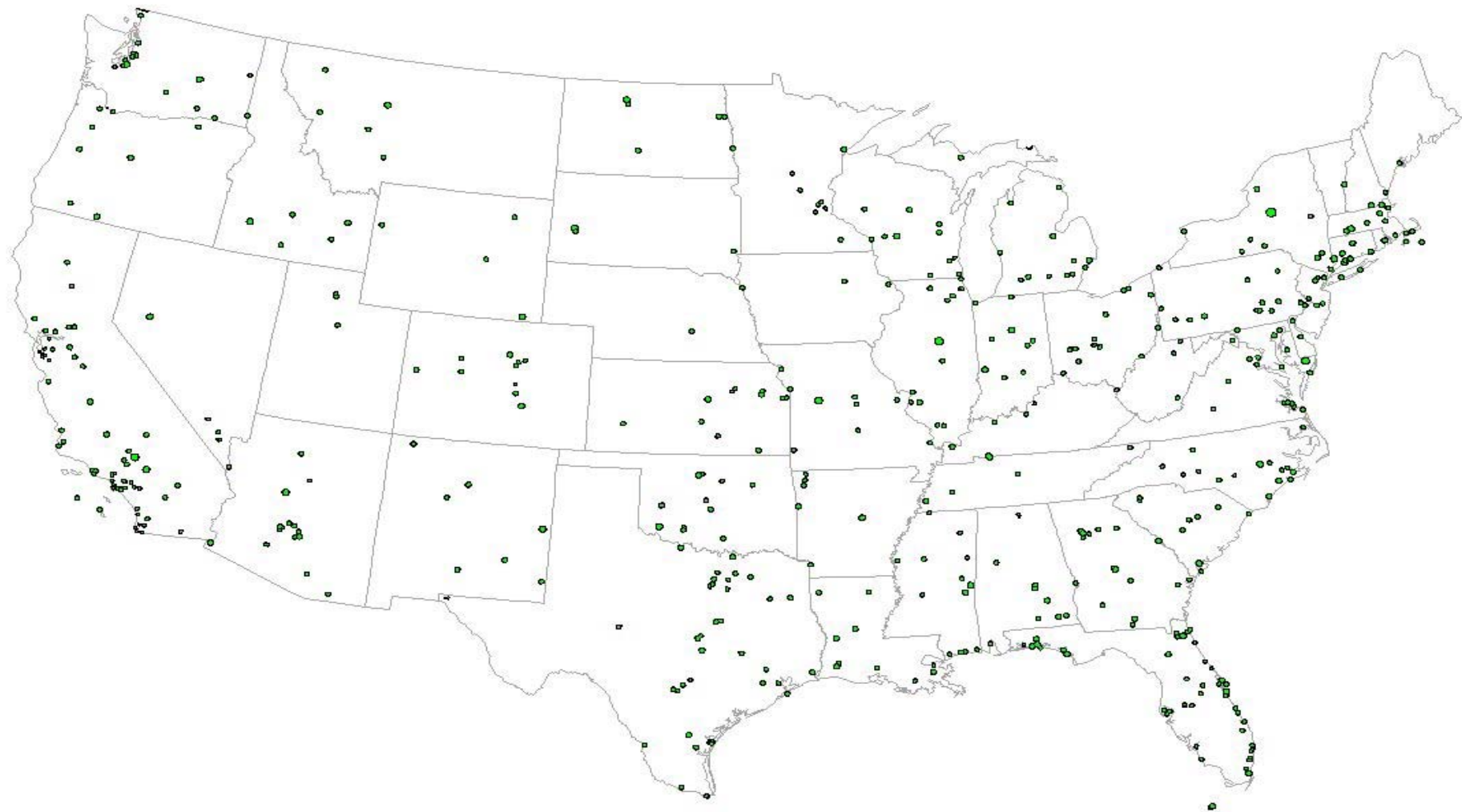
Class B



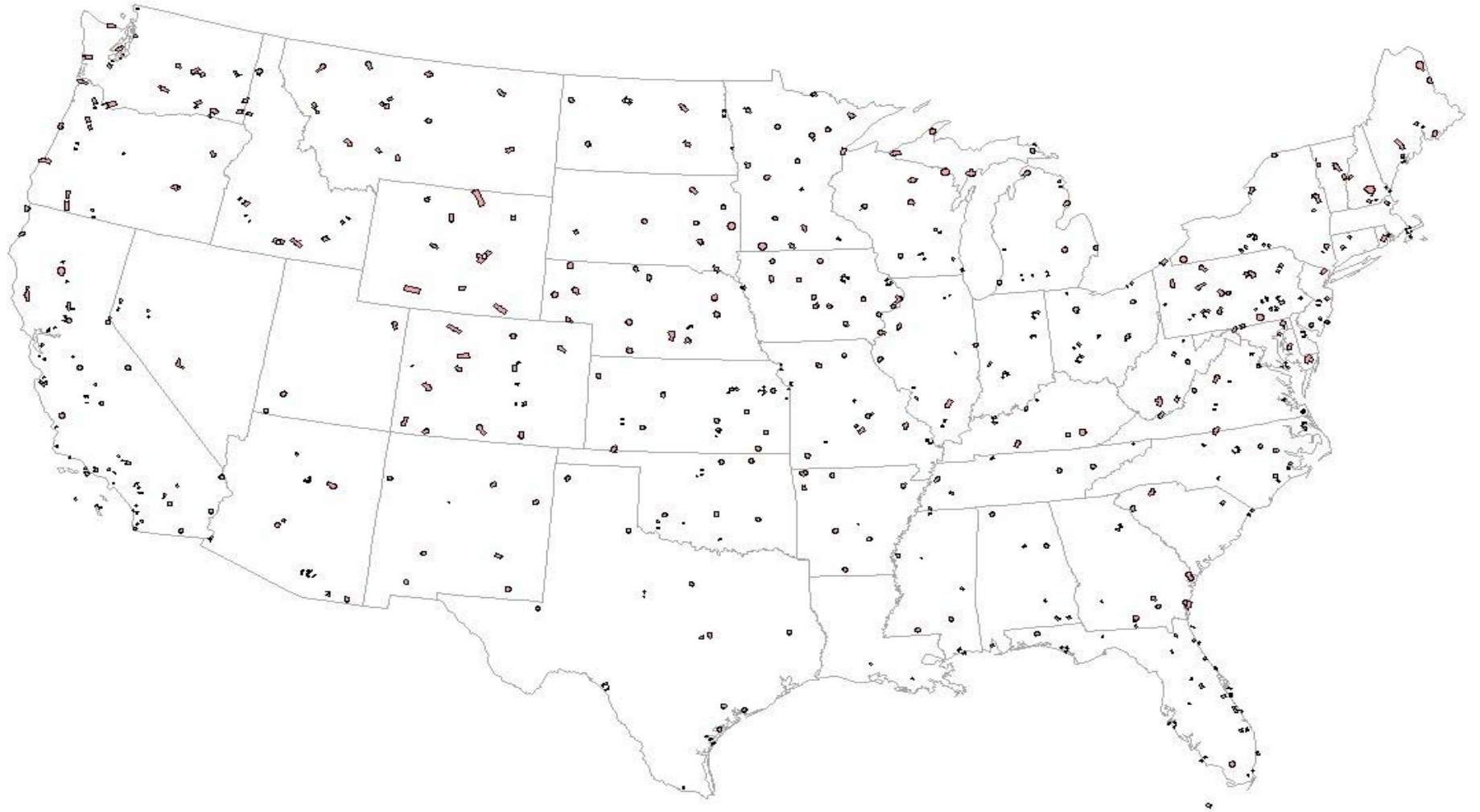
Class C



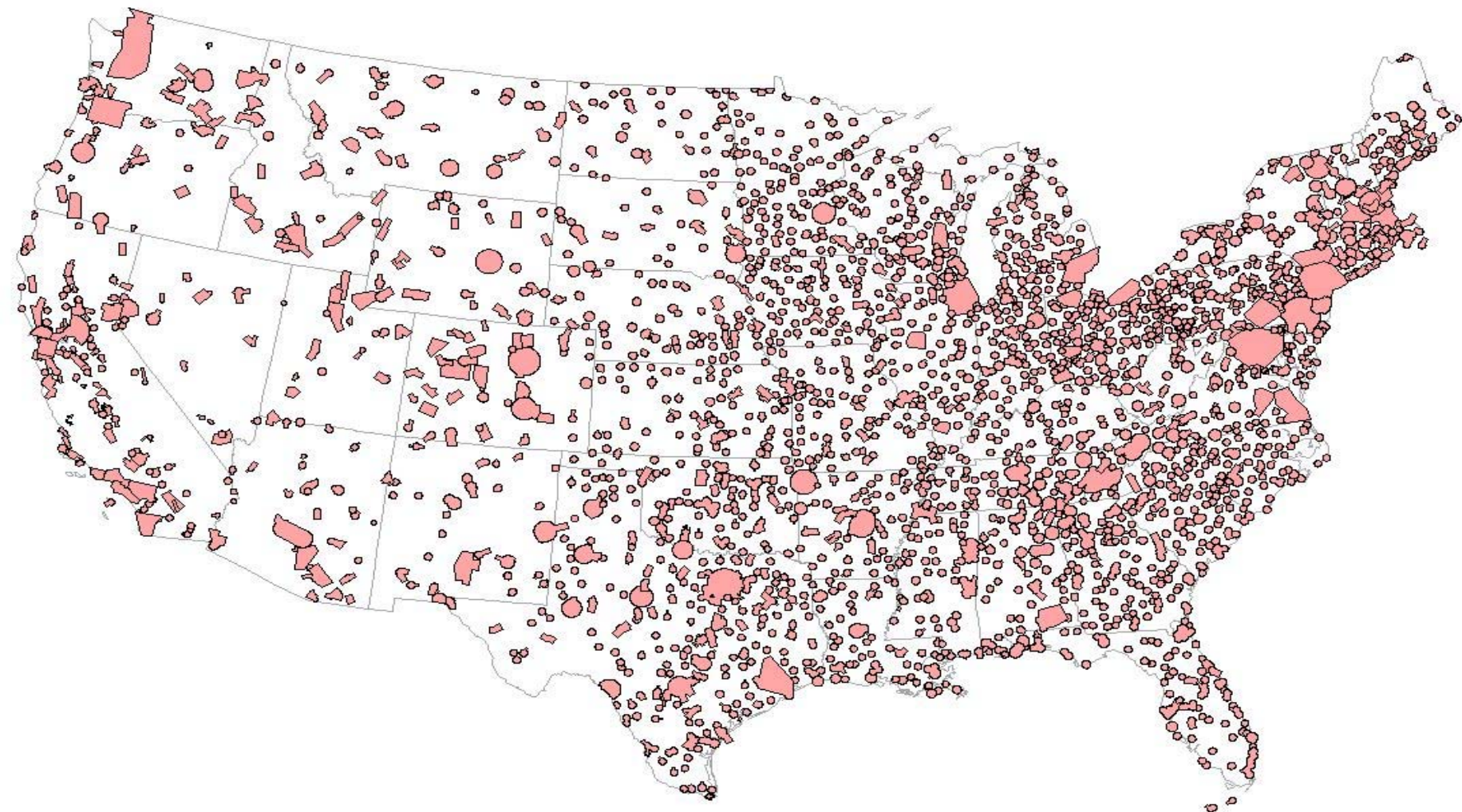
Class D



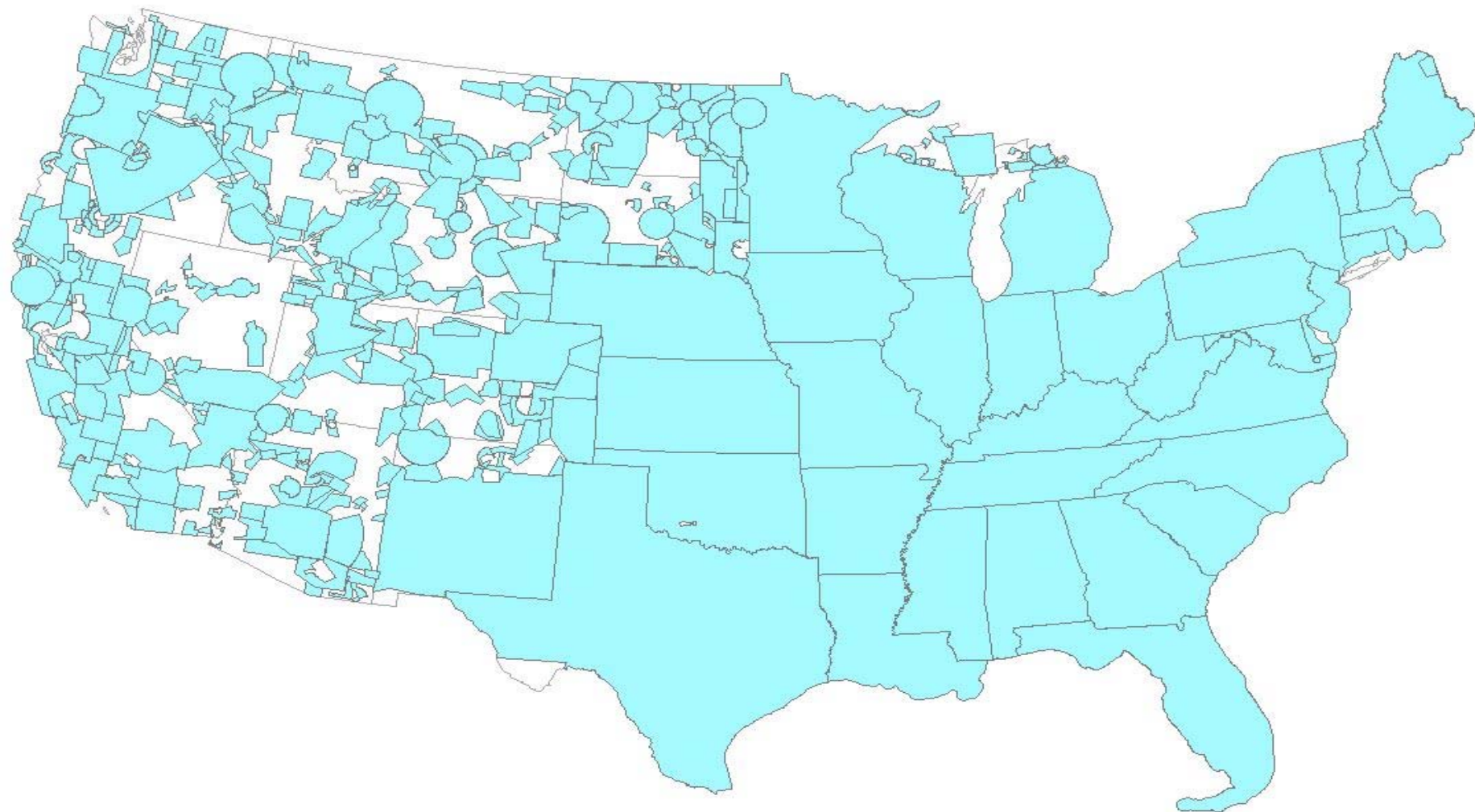
Class E Surface



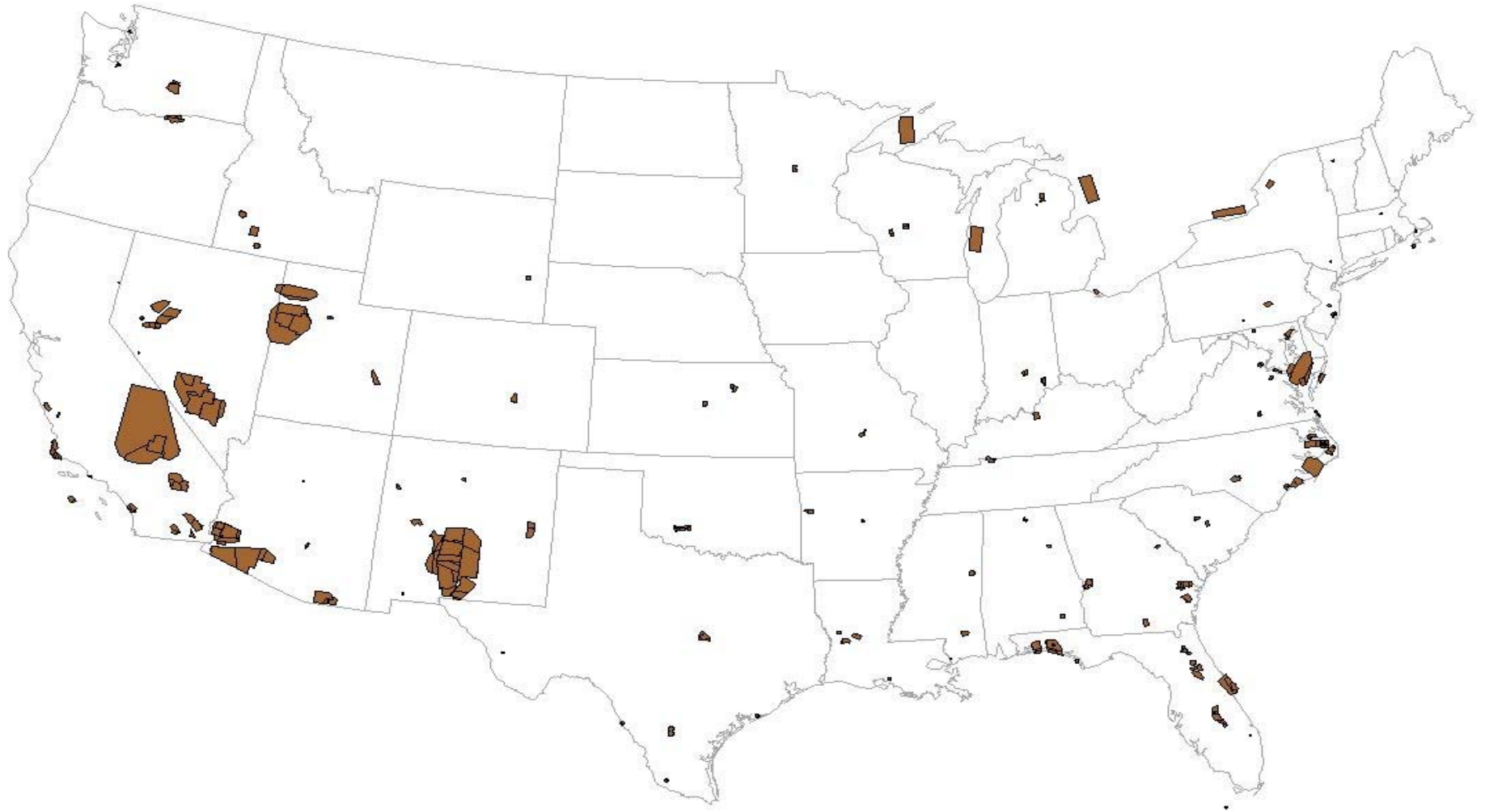
Class E 700'



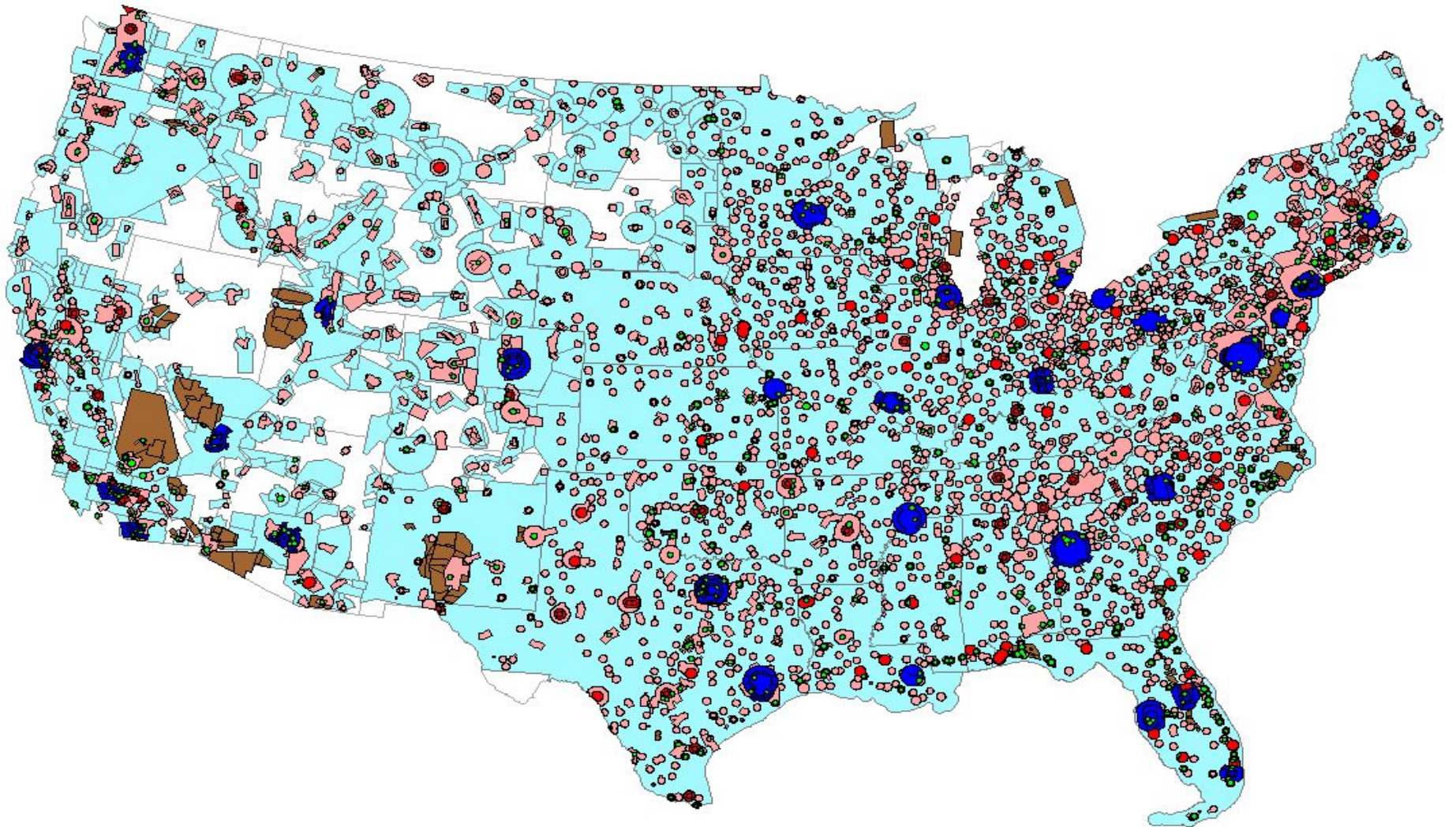
Class E Above 700'



No Fly



US Terminal Airspace



U.S. Terminal Airspace Situation

- There are very few areas requiring Area 1 accuracies.
- Economics tells us it's cheaper to buy products in bulk, the entire United States should be surveyed to at least Area 2 requirements.



Area 2 Obstacle Requirements

- Penetrate conical surface of 1.2% (83:1) slope from a 180 meter rectangle surrounding all runways reaching 120 meters at 10 kilometer distance
- Vertical Accuracy – 3 meters
- Vertical Resolution – 0.1 meter
- Horizontal Accuracy – 5 meters
- Confidence Level – 90%
- Data Classification-essential
- Integrity Level – 1×10^{-5}
- Maintenance Period – as required

Does the US Meet Area 2 Obstacle Requirements?

Legally, Yes

14 CFR Part 77.13 requires the reporting to the FAA, any construction or alteration which penetrates a 1% (100:1) slope out to 20,000 feet from the nearest point of the nearest runway of each airport with at least one runway more than 3,200 feet in actual length. ***Technically***, an analysis of existing data will be required to determine if our data meets the eTOD accuracies.



Area 2 Terrain Requirements

- Post Spacing – 1 arc second (approx 30 meters)
- Vertical Accuracy – 3 meters
- Vertical Resolution – 0.1 meter
- Horizontal Accuracy – 5 meters
- Confidence Level – 90%
- Data Classification-essential
- Integrity Level – 1×10^{-5}
- Maintenance Period – as required

Does the US Meet Area 2 Terrain Requirements?

No

As of this date, there is not 100% coverage of *publicly* available digital elevation data of the United States that meets or exceeds the Area 2 terrain requirements specified by ICAO.

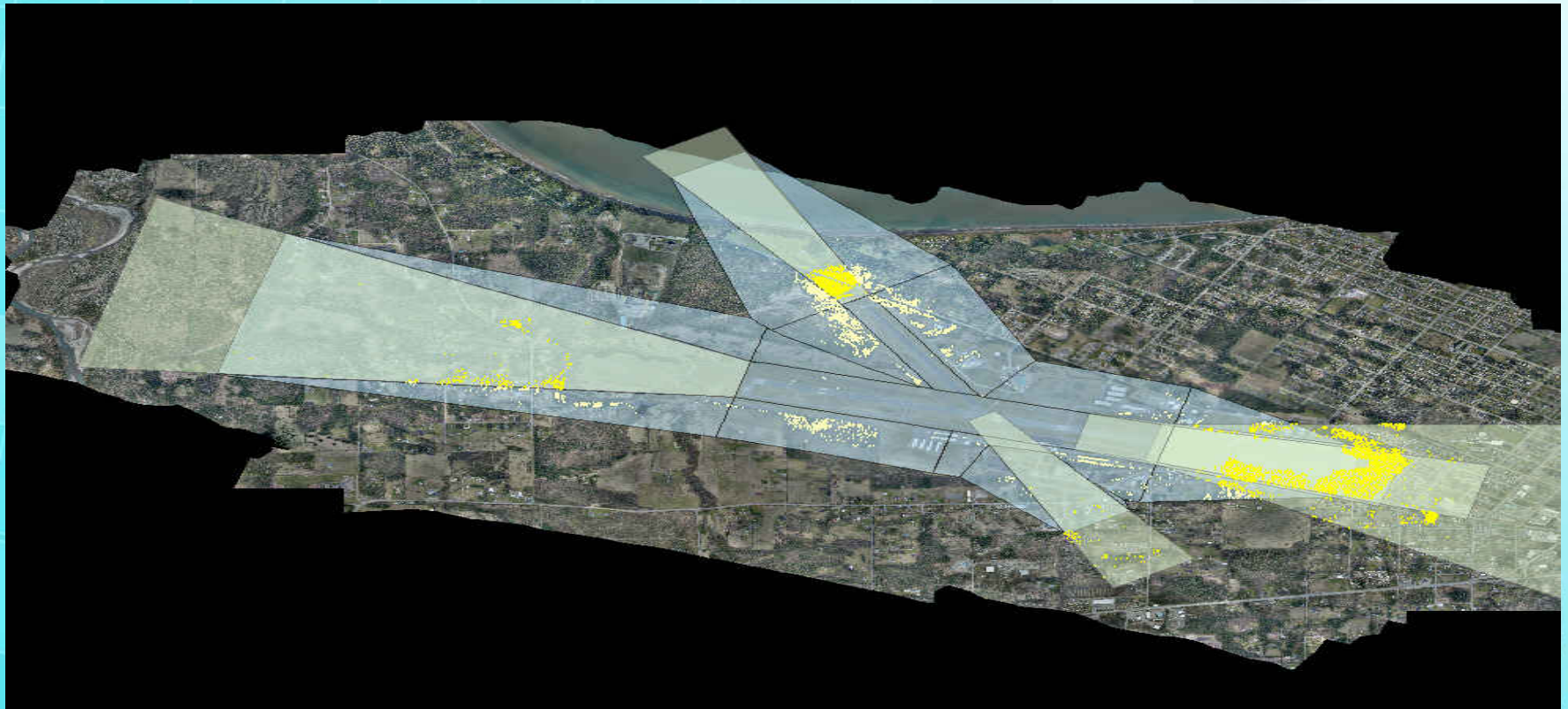
How do we meet the Area 2 Terrain Requirement?

- Airborne Laser Terrain Mapping utilizing Light Detector and Ranging Data (LiDAR)
- Airborne (Interferometric) Synthetic Aperture Radar (IFSAR)
- Commercial Satellite Imagery
- Satellite (Interferometric) Synthetic Aperture Radar (IFSAR)



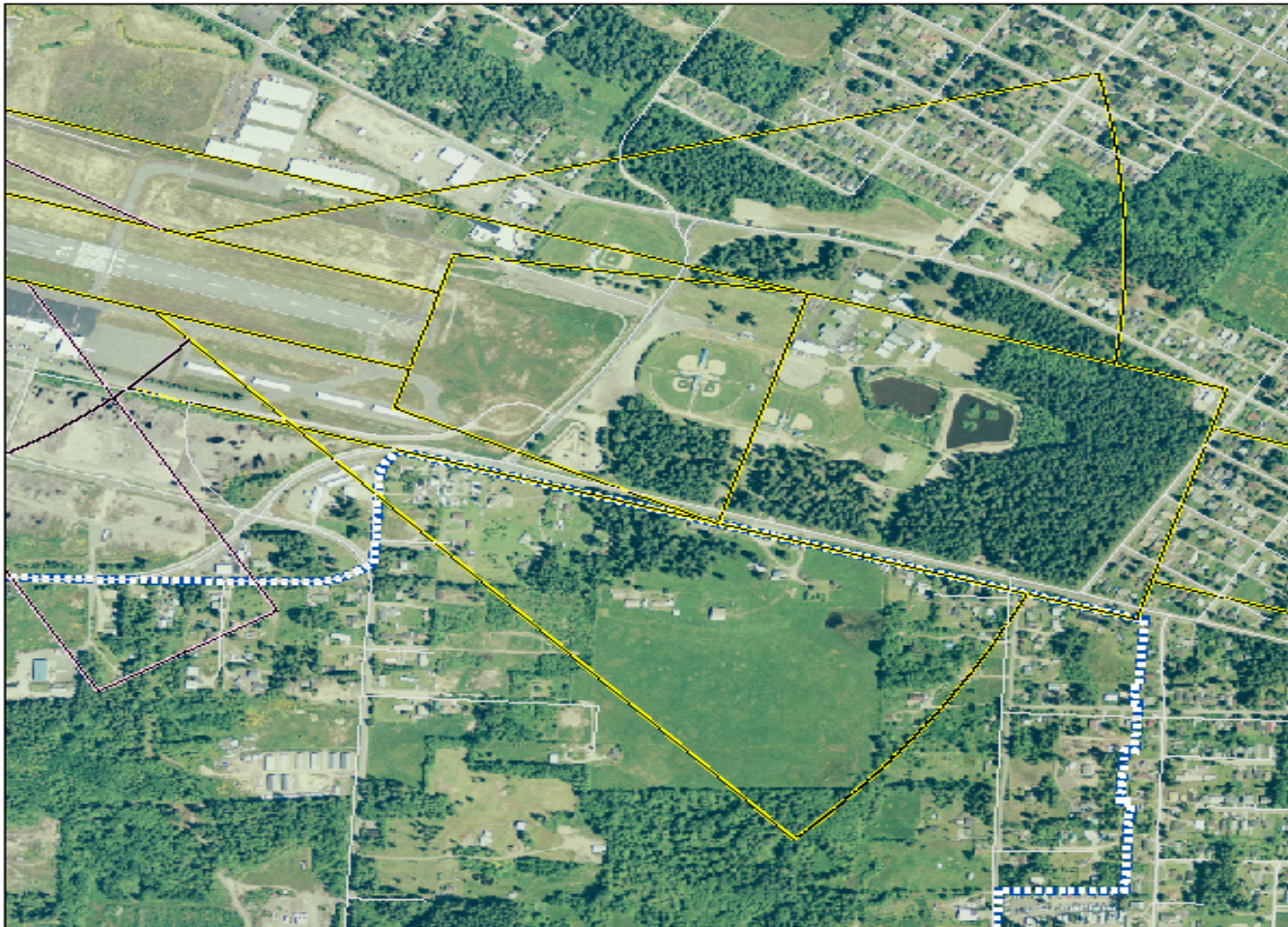
LiDAR

Port Angeles, Washington LiDAR Survey,
CFR Part 77 Approach, Transitional, and
Departure Surfaces composite image



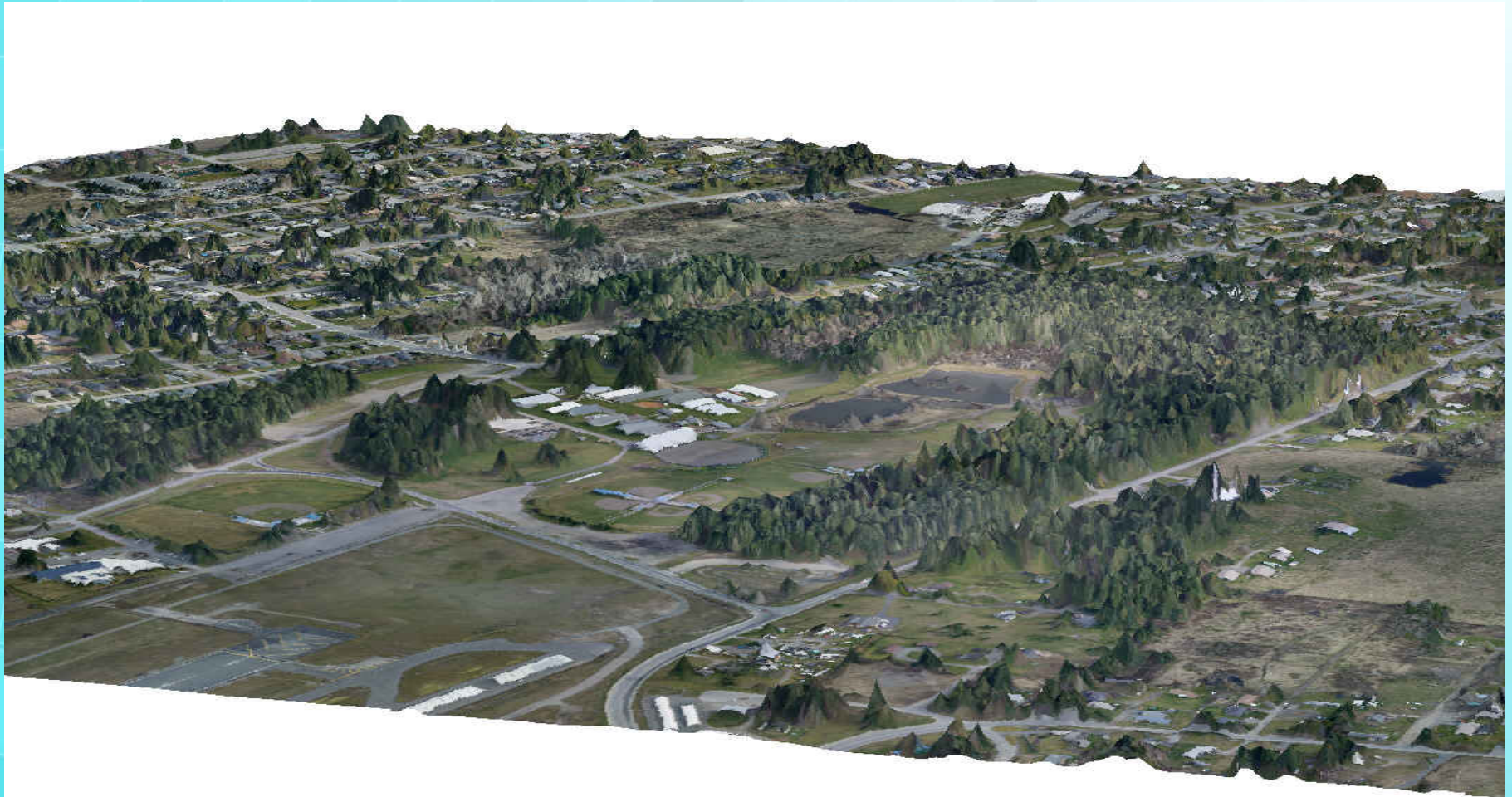
LiDAR Orthorectified Image

Runway 26 Approach



City of PA Boundary
Runway 08/26 Airport
Compatibility Zone Boundaries

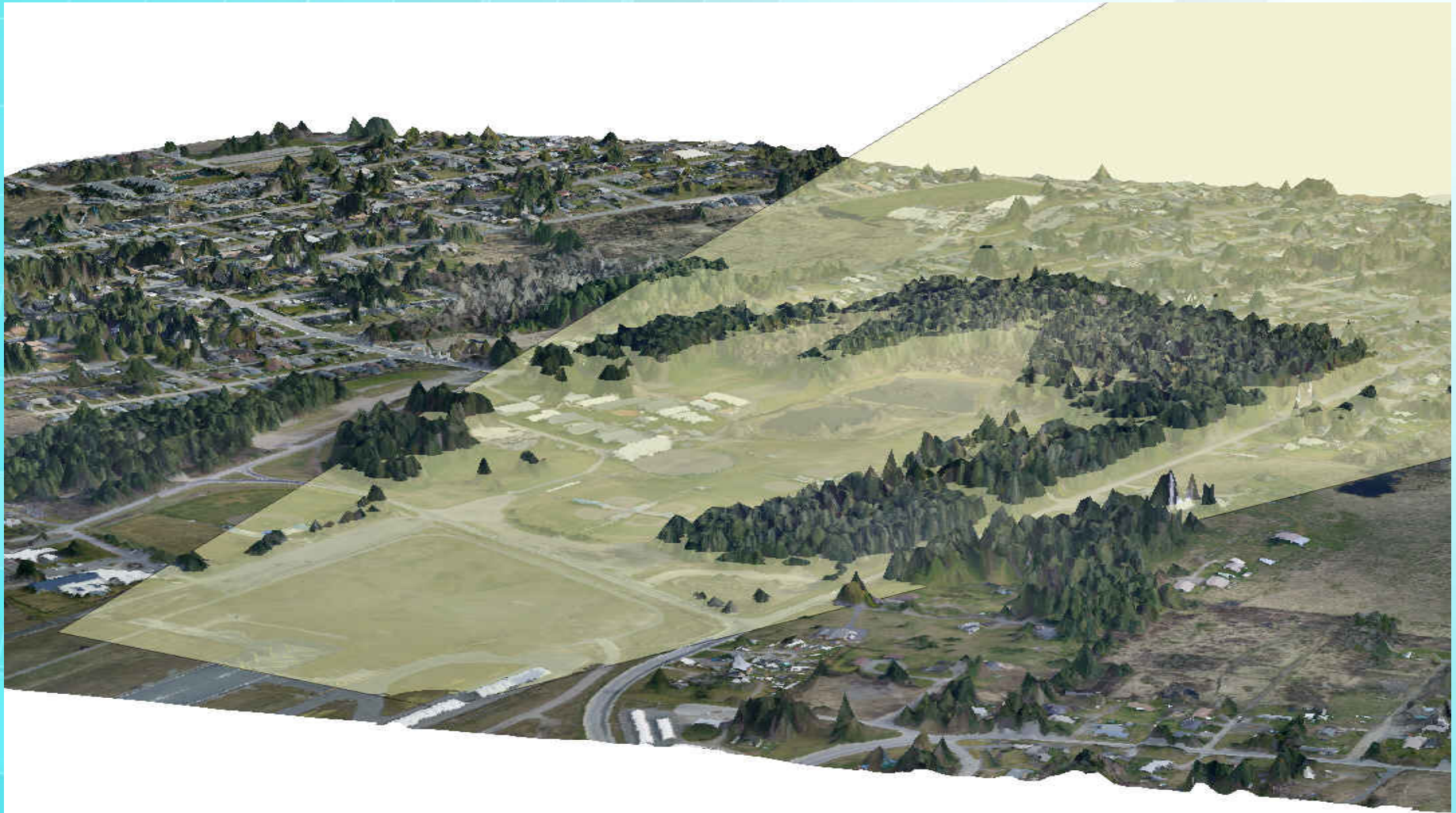
LiDAR Generated 3D View of Runway 26



LiDAR 20:1 Approach Surface, Runway 26



LiDAR 40:1 Departure Surface Runway 26



LiDAR Advantages

- Exceeds accuracy requirements for Area 2 data
- Collection process for terrain is nearly fully automated with higher resolutions than some photogrammetric methods
- Data collected easily imported into commercially available GIS packages
- Data changes easy to detect from re-survey

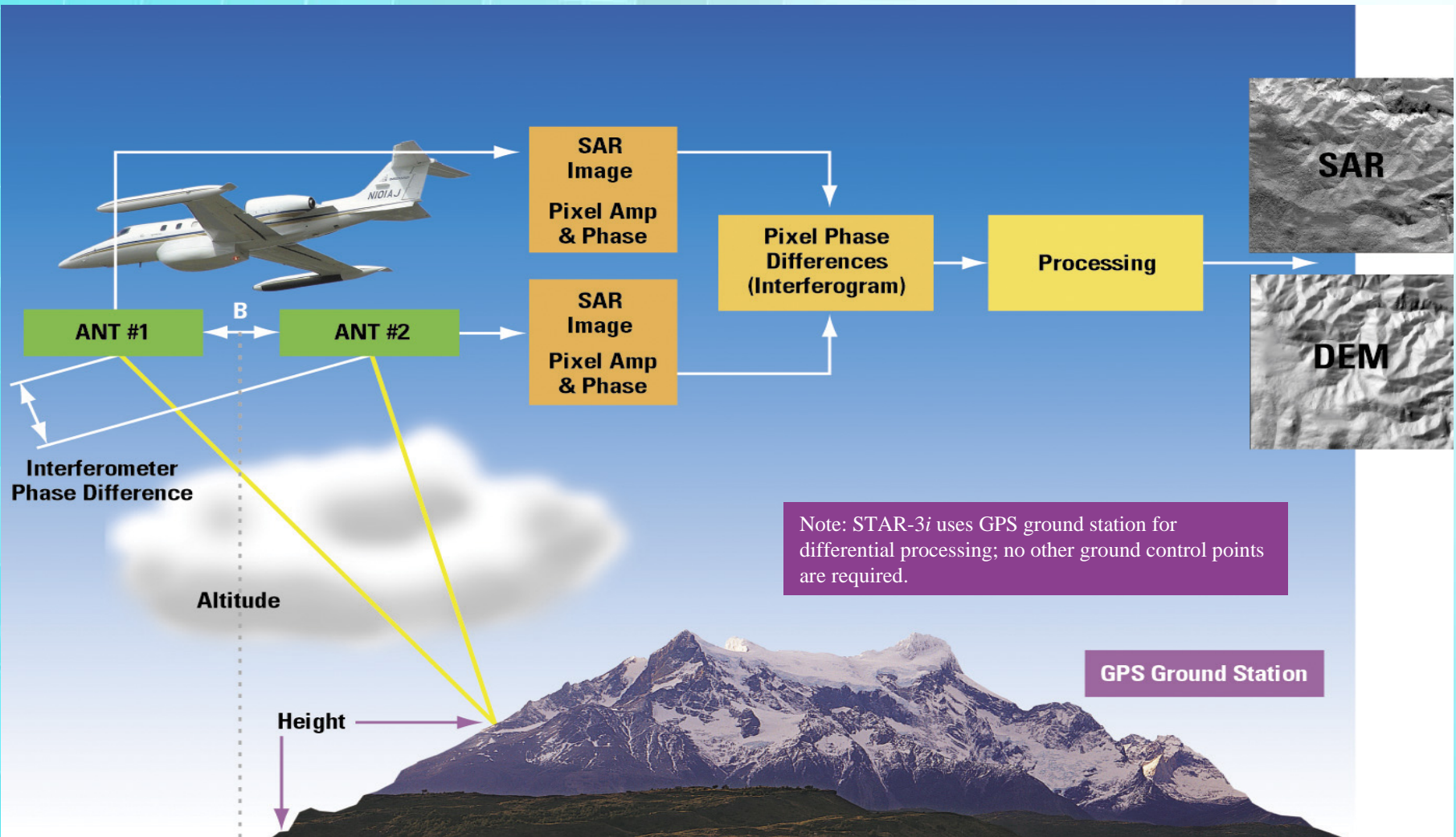
LiDAR Limitations

- Can not observe very thin objects (antennae) requiring ground survey verification
- Excessive cost: \$60,000 to conduct the survey and \$26,000 for data processing = \$86,000 for delivered product
- $\$86,000 \times 5,300$ public use airports in the United States = \$455,800,000 does not include entire TCA
- LiDAR is a possible solution for Area 2 but not currently cost effective
- Could be cost effective as the technology advances



Airborne IFSAR

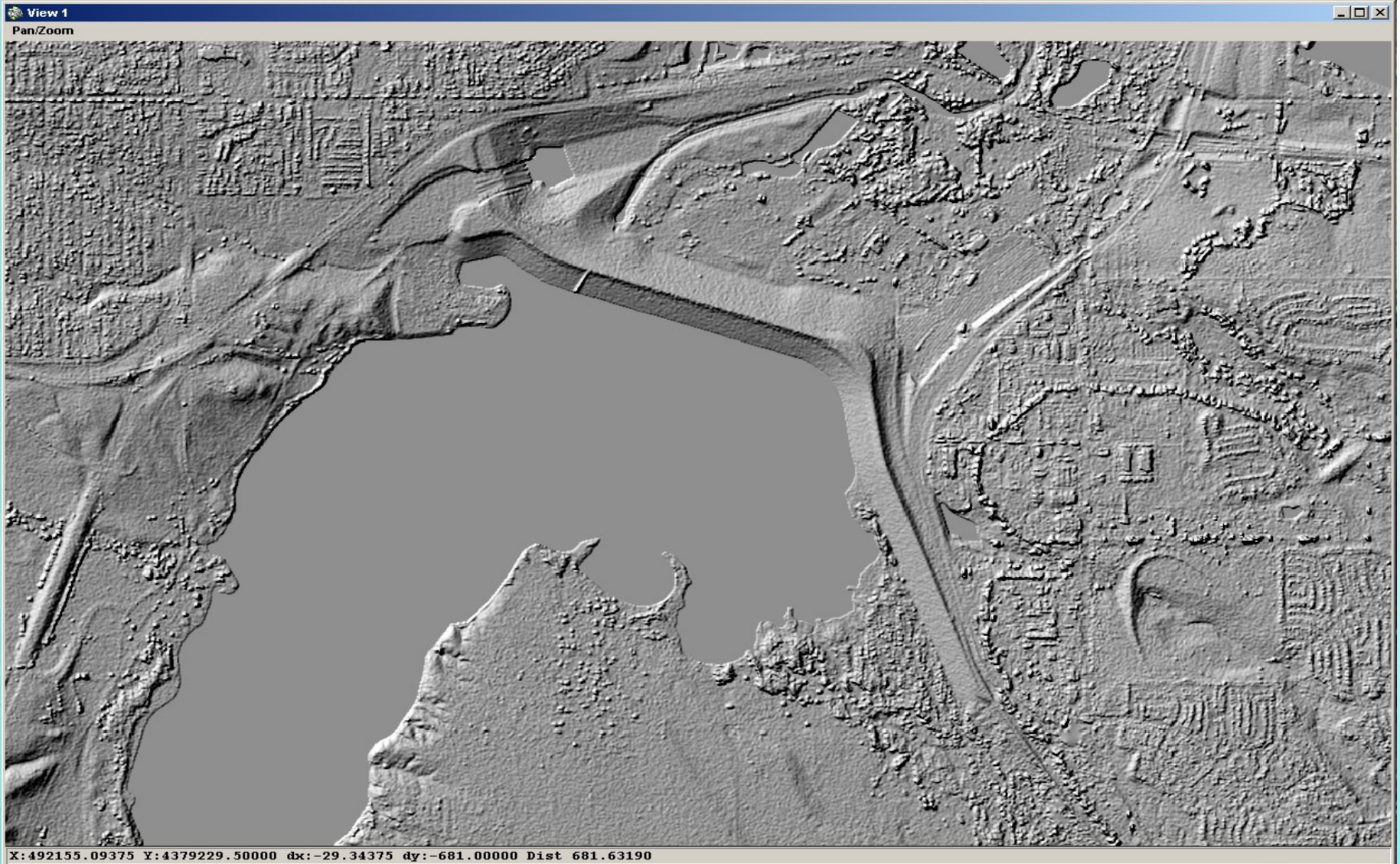
IFSAR Collection Process



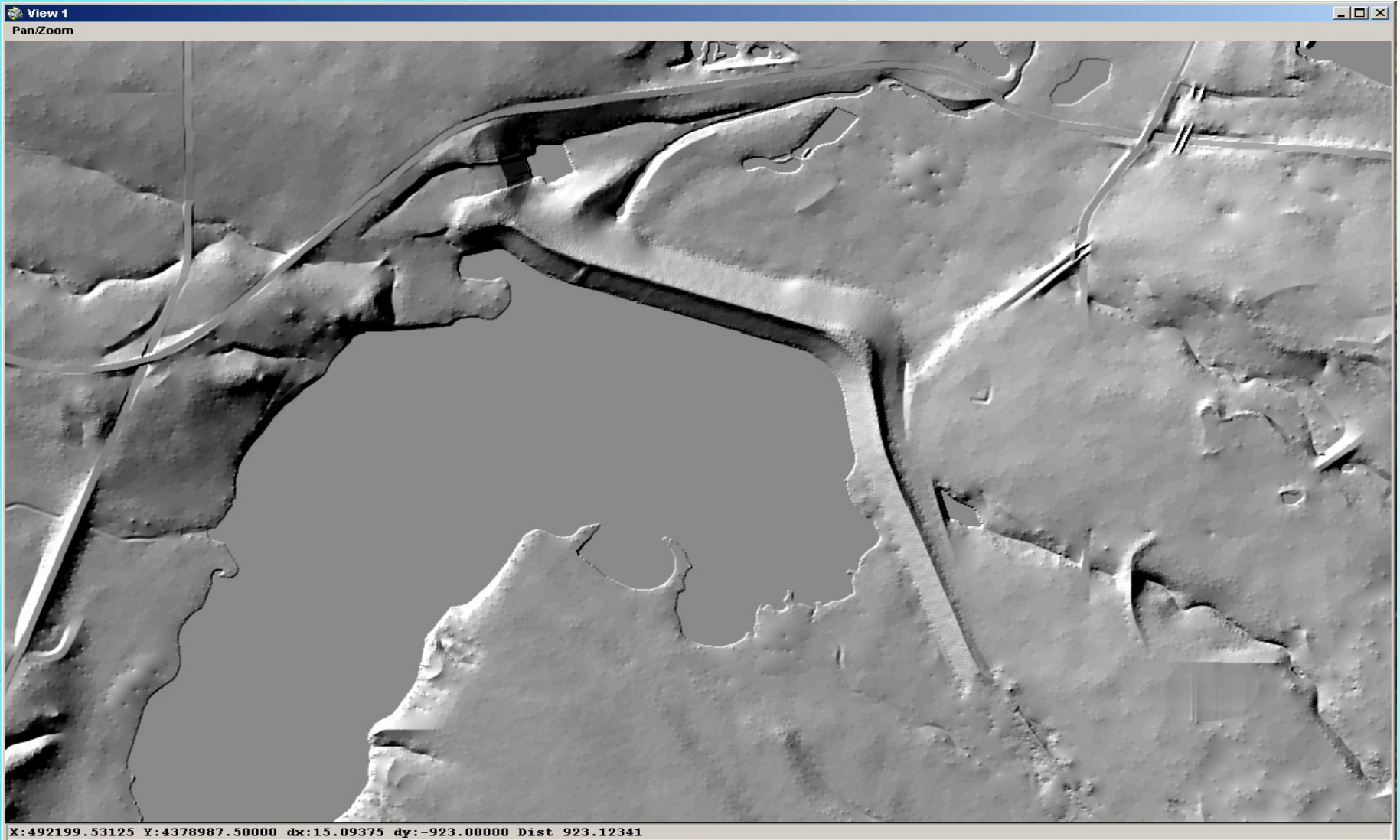
IFSAR Products

- Digital Surface Model (DSM)
 - A first surface measurement (reflected radar pulse)
- Digital Terrain Model (DTM)
 - Bare earth measurement (Process & Edit)
- Ortho-rectified Radar Image (ORI)
 - Black & White
- National Color Image Layer (NCIL)
 - ORI fused with colour Landsat
 - Selected urban areas (optical imagery)
- Selected vector products
 - Contours

IFSAR DSM



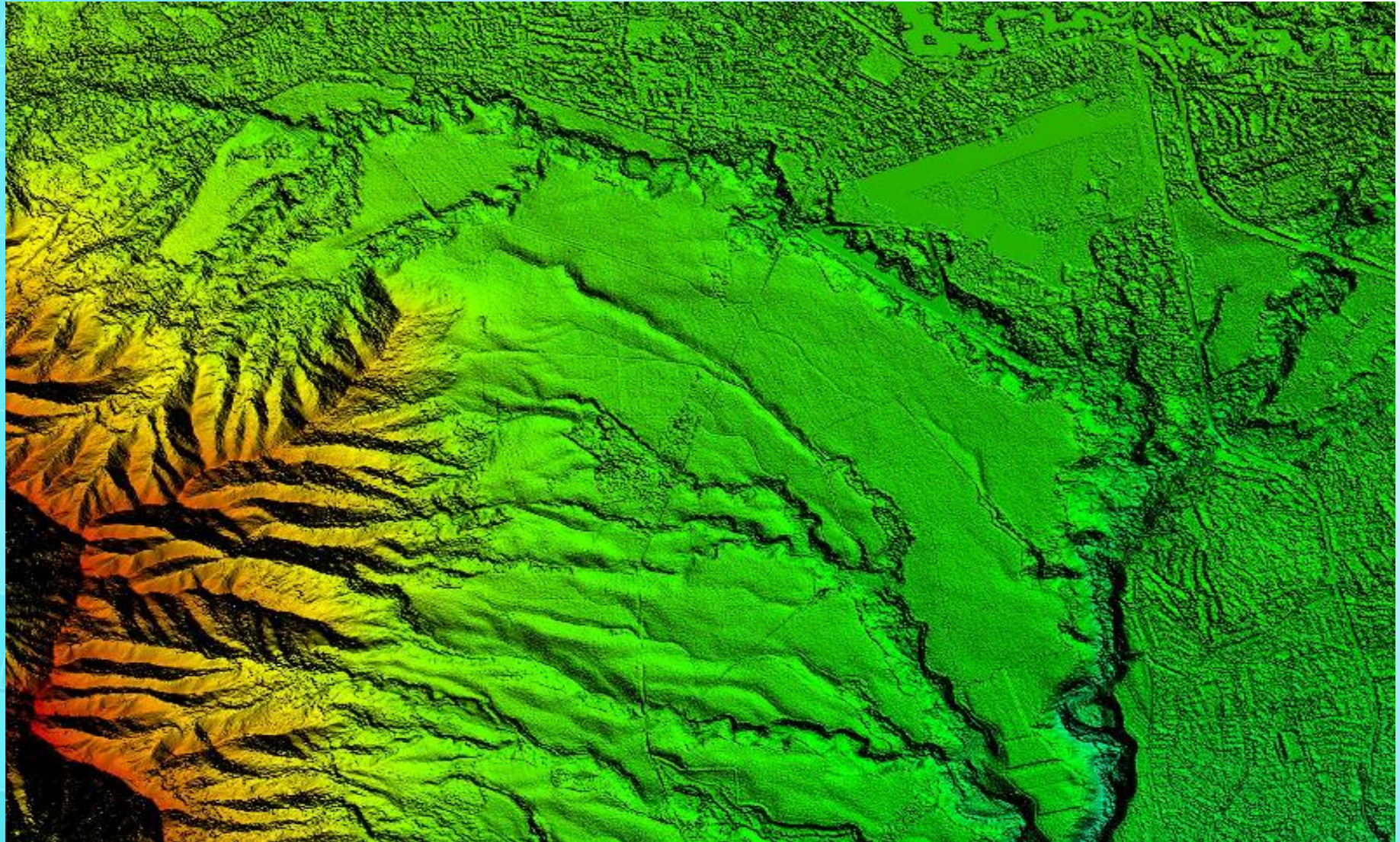
IFSAR DTM



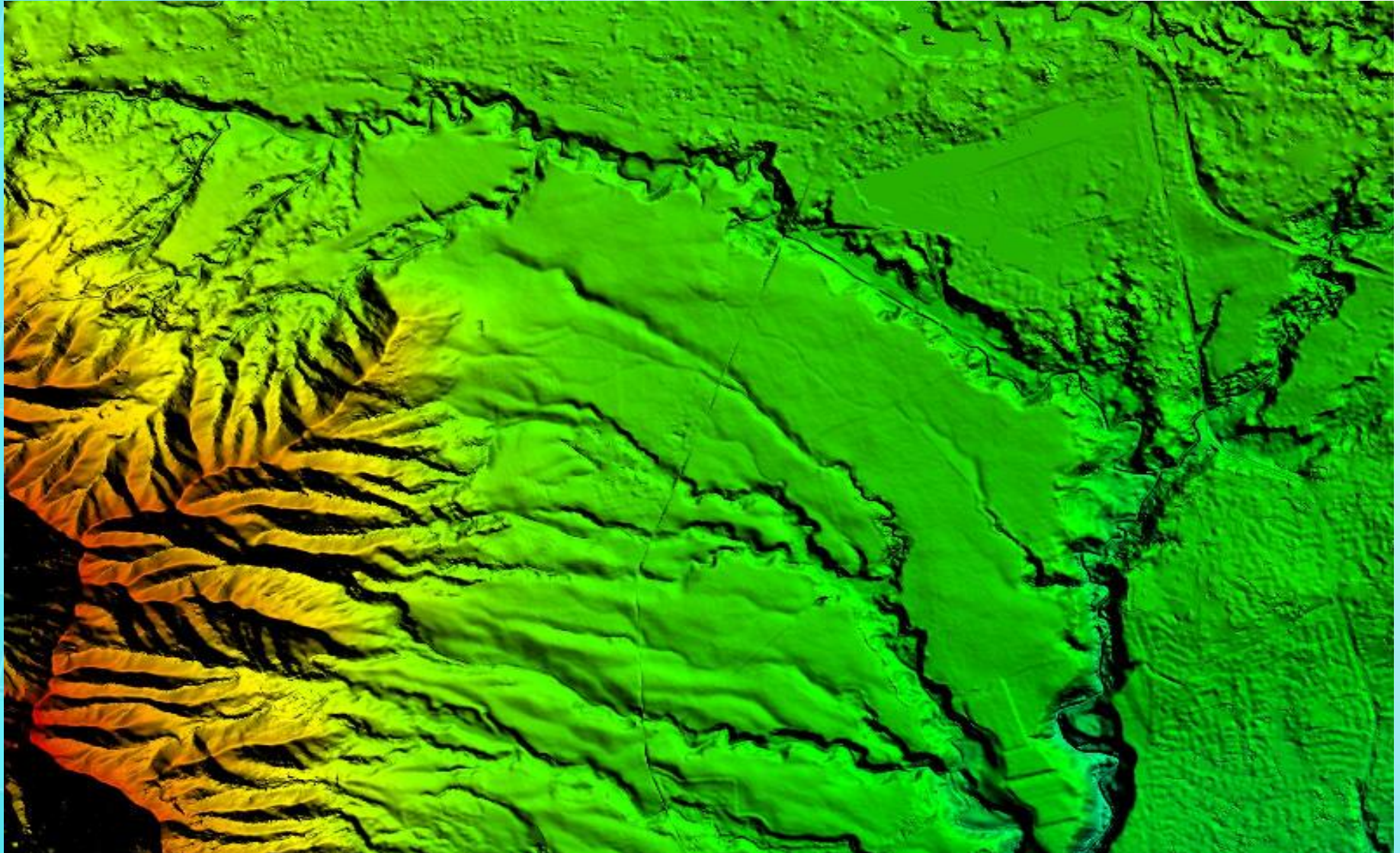
IFSAR ORI



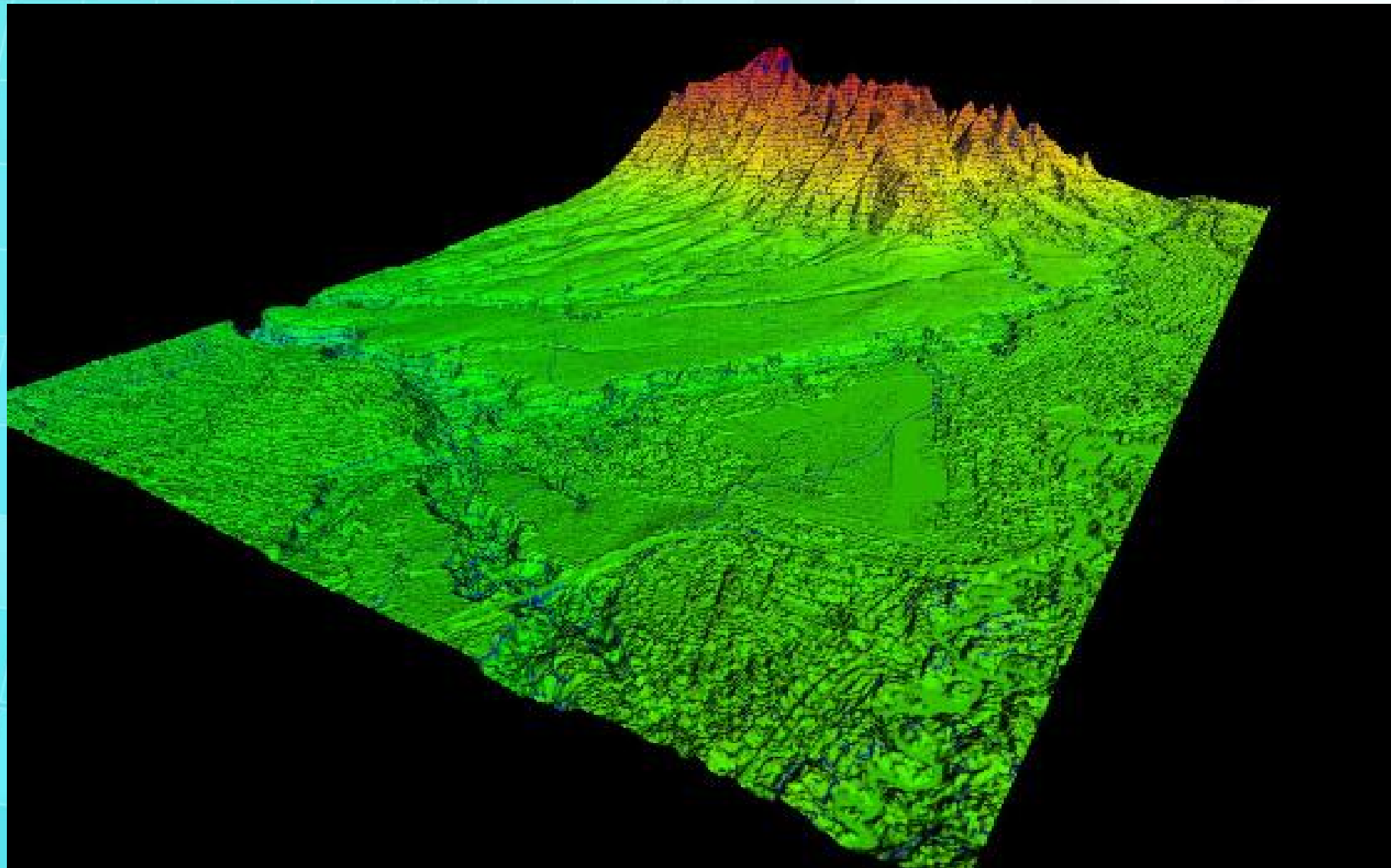
IFSAR COLOR DSM



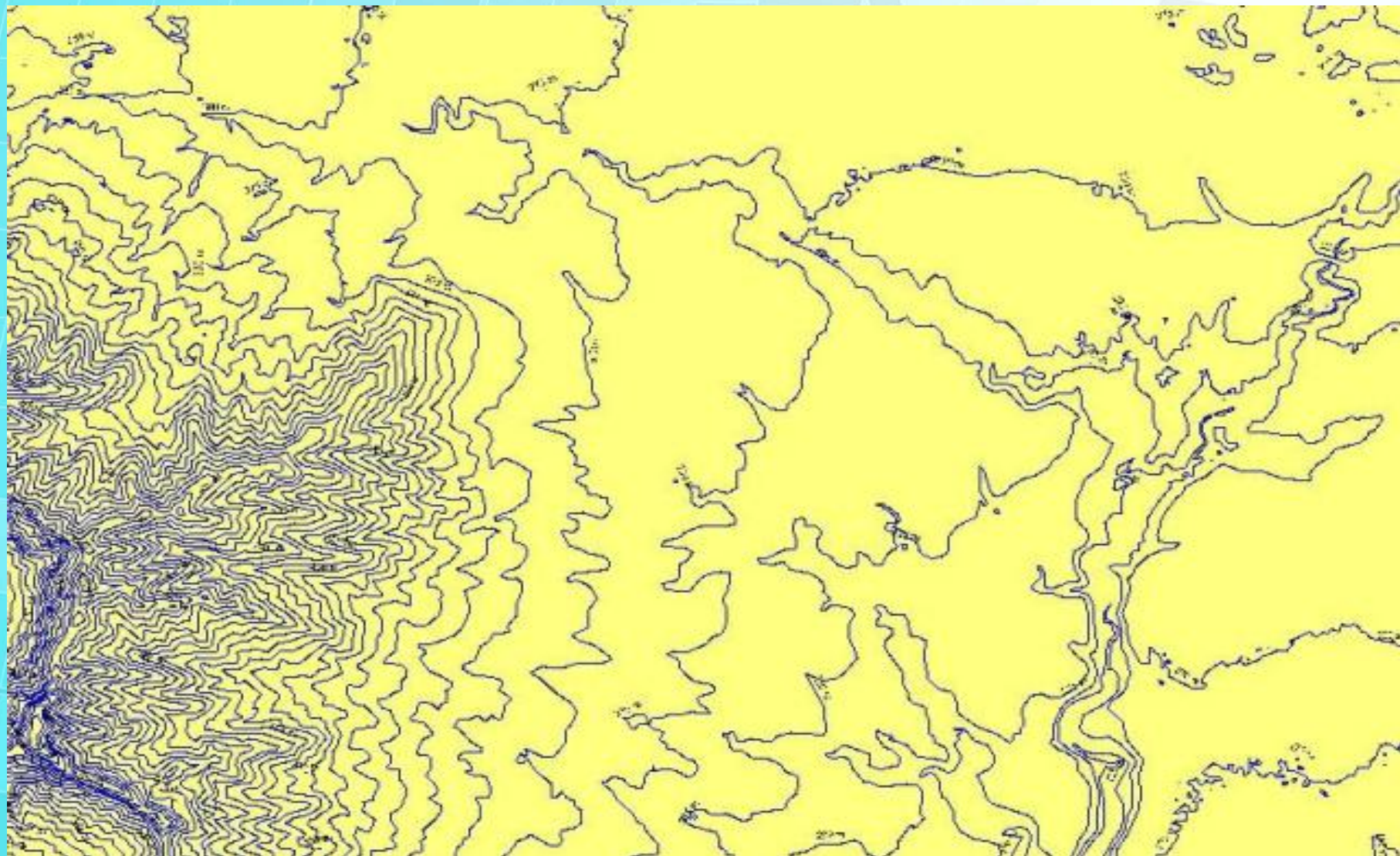
IFSAR COLOR DTM



IFSAR 3D



IFSAR Vector Contours



IFSAR Advantages

- Meets or exceeds accuracy requirements for Area 2 data
- Collection process for terrain is nearly fully automated with higher resolutions than some photogrammetric methods
- Data collected easily imported into commercially available GIS packages
- Data changes easy to detect from re-survey

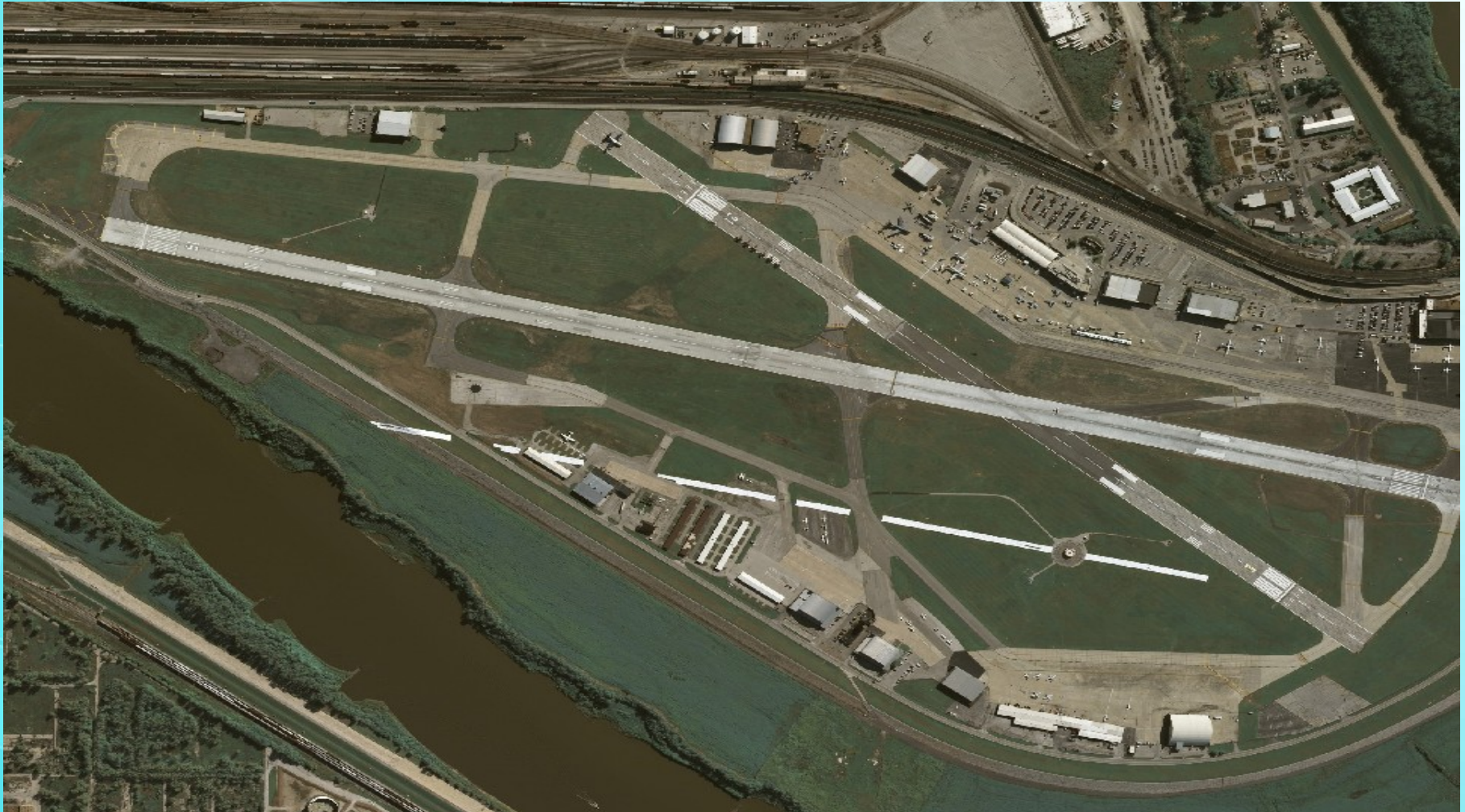
IFSAR Limitations

- Can not observe very thin objects (antennae) requiring ground survey verification
- Vendor claims price for core product set of the continental United States, Hawaii, & Puerto Rico (excluding Alaska and possessions) approximately \$25,000,000
- IFSAR possible Area 2 solution for electronic terrain

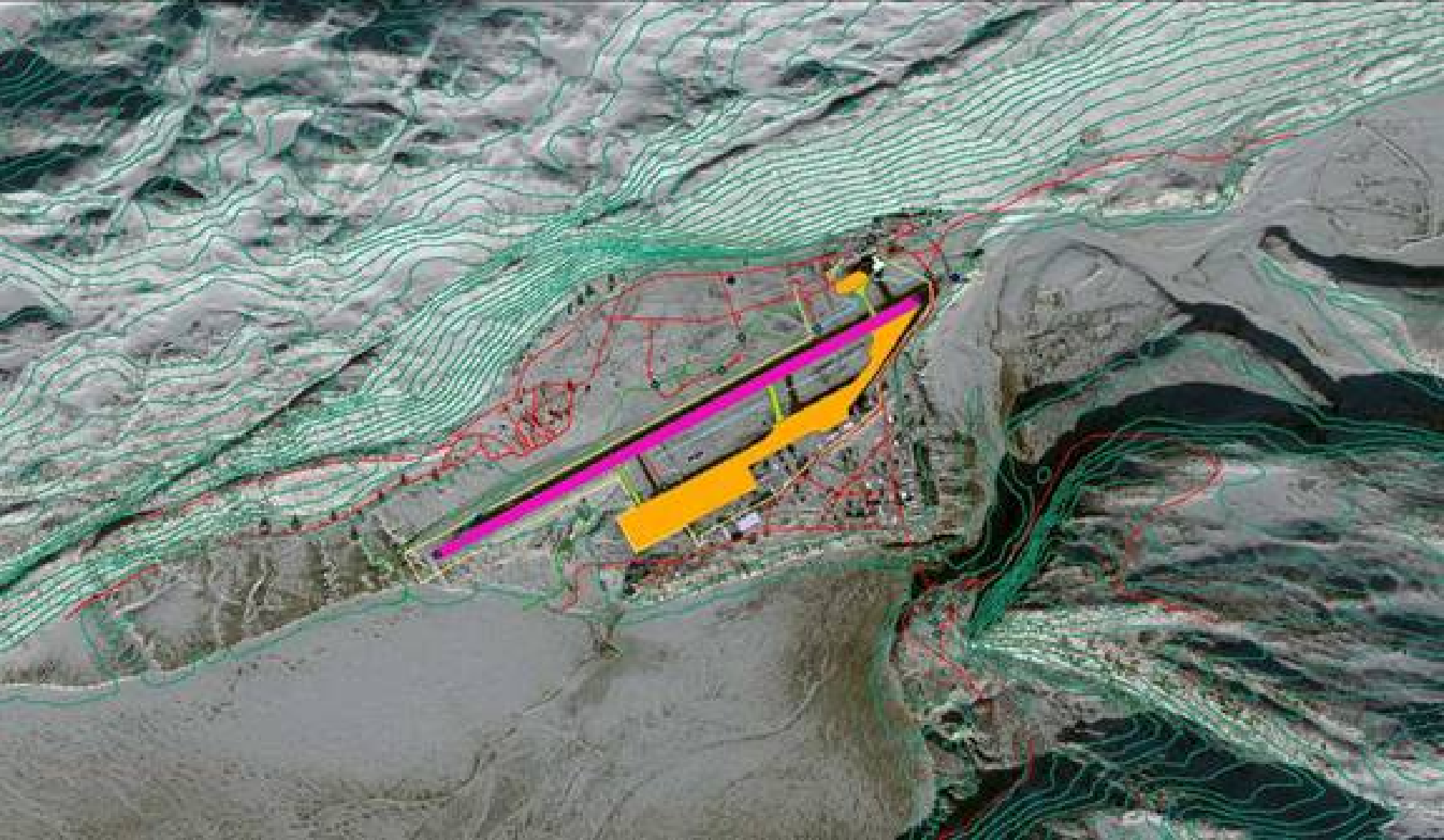


Commercial Satellite Imagery

Kansas City (MKC) Airport 1 Meter



Satellite Imagery Airport Mapping



Next Generation Satellite Imagery

- Vendor claims next generation system provide grounds resolution of 0.41 meter (1.34 feet) stereo panchromatic (0.5 meter commercial) and 1.65 meter (3.54 feet) multispectral or color imagery
- Vendor claims next generation system can detect objects 16 inches in size and map to within 3 meters horizontally without ground control points
- Vendor will provide sample data as proof of concept to satisfy Area 2 requirements

MCI Control Tower

1 Meter



.41 Meter



Satellite (Interferometric) Synthetic Aperture Radar (IF)SAR

Later this year, a vendor plans to place in orbit a second SAR satellite in tandem with an existing SAR satellite creating the first bistatic mission. The expected result is a highly accurate digital elevation model with a 2 meter (relative) 10 meter (absolute) vertical accuracy, and 3 meter (relative) 10 meter (absolute) horizontal accuracy at a 12 meter post spacing.



Area 3 (Aerodrome/Heliport Area) & Area 4 (Category II or III Operations Area)

- Requirements met by FAA Advisory Circulars (AC) , AC150/5300-16, 17, & 18.
- AC 150/5300-18B specifically addresses areas 3 & 4 which is currently under legal review
- Data collected for areas 3 & 4 will be stored in Airports GIS



Thank You

