# ALASKA STATEWIDE DIGITAL MAPPING INITIATIVE: MAPPING ALASKA FOR THE FIRST TIME

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## ABSTRACT

Alaska has been a state for over 50 years, but the 1" = 1-mile (1:63,360-scale) topographic quadrangle maps of Alaska, produced by the U.S. Geological Survey (USGS) using 1950's technology, were never produced to National Map Accuracy Standards (NMAS). Some maps have errors 100 times larger than allowed by the NMAS, with mountains mapped several miles away from their true locations and with elevations being in error by hundreds to thousands of feet. Produced from these inaccurate and obsolete topographic maps, the digital layers in The National Map are no better. In fact, the National Elevation Dataset (NED) for Alaska is so poor that digital orthophotos of the state have never been produced, inhibiting the proper stewardship of vast natural resources by state and federal agencies. The Alaska Statewide Digital Mapping Initiative (SDMI) is trying to get Alaska mapped digitally for the first time. This paper discusses the needs for a Digital Elevation Model (DEM) for Alaska and technical alternatives documented in the Alaska DEM Workshop Whitepaper, as well as the continuing need to obtain cooperative funding for the elevation and other layers of The National Map for Alaska.

Key words: DEM, NED, SDMI, IFSAR

## INTRODUCTION

In his testimony to Congress on December 5, 1884, John Wesley Powell, the 2nd Director of the USGS, stated: "A Government cannot do any scientific work of more value to the people at large, than by causing the construction of proper topographic maps of the country." In Alaska today, after 50 years of statehood, an elevation data "log-jam" continues to prevent topographic maps from being produced at any scale to National Map Accuracy Standards (NMAS), either in the form of paper topographic maps or digital topographic data.

By the 1970s, USGS had completed production of topographic quadrangle maps, compiled to NMAS standards at a scale of 1" = 2,000' (1:24,000-scale), for 49 of the 50 states. In Alaska, topographic maps were produced at a lesser scale of 1" = 1-mile (1:63,360-scale), but they were never produced to the NMAS because of poor survey control in Alaska and GPS technology being yet unknown at that time. Some map errors in Alaska are 100 times larger than allowed by the NMAS, with mountains mapped several miles away from their true horizontal locations and with elevations being in error by hundreds to thousands of feet. Once printed, only a few of USGS' topographic quadrangle maps nationwide have ever been updated, regardless of scale or location.

In this age of Google Earth, Virtual Earth, and cell phones with GPS, The National Map of the 21st century must be digital, for ease of maintenance/update, dissemination and use via the Internet. It will be a seamless, continuously maintained, nationally consistent set of base geographic data, developed and maintained through partnerships, available on-line for a large variety of applications, and printable. The eight basic framework layers of The National Map, and organizations with Circular A-16 responsibilities for maintaining those layers, are as follows:

1. Orthoimagery: USDA (Farm Services Agency), and DOI (USGS)
2. Elevation: DOI (USGS)
3. Hydrography: DOI (USGS)
4. Boundaries: DOI (BLM & MMS), DOC (NOAA), and Department of State
5. Transportation: DOT
6. Land Cover: DOI (USGS & USFWS-Wetlands), USDA-Vegetation
7. Structures: GSA
8. Geographic Names: DOI (USGS)

The goal of The National Map is to become the nation's source for trusted, nationally consistent, integrated and current topographic information available online for a broad range of uses. This can only succeed when all layers satisfy established accuracy standards and are correctly georeferenced to fit the two primary base map layers: (1) orthoimagery for 2-D accuracy and (2) elevation for 3-D accuracy.

After five decades as a state, Alaska's mapping needs remain unmet for all layers of The National Map:

1. Orthoimagery: Alaska is the only state with no statewide orthoimagery at any scale. Satellite imagery cannot be accurately orthorectified because of the inaccurate elevation data. See example at Figure 1.
2. Elevation: The National Elevation Dataset (NED) of Alaska is the "log-jam" that limits other layers, including orthoimagery, hydrography and boundaries. Alaska is the only state with no DEM, to any NMAS standard, and the only state with gravity data so poor that elevations from ground or aerial GPS surveys have uncertainties at the ±2-meter level rather than ±2-cm level as elsewhere, the reason for NOAA's GRAV-D initiative (Gravity for the Re-definition of the American Vertical Datum).
3. Hydrography: The National Hydrography Dataset (NHD) of Alaska is the poorest, largely because it is based on inaccurate 1:63,360-scale maps (with inaccurately-mapped mountains and rivers), rather than accurate 1:24,000-scale maps used elsewhere.
4. Boundaries: Alaska is the only state where boundary lines cannot be delineated because of unavailable survey control, inaccurately-mapped rivers, and no authoritative source of orthoimagery.
5. Transportation: In this state with most reliance on general aviation, Alaska is the only state in non-compliance with International Civil Aviation Organization (ICAO) requirements for Electronic Terrain and Obstacle Database (eTOD) data to support navigation under Instrument Flight Rules (IFR), where weather conditions are such that IFR procedures are frequently required, and where general aviation accidents are the most severe from Controlled Flight Into Terrain (CFIT). Alaska is the only state with no orthophotos for accurate alignment of roads, railroads, and trails.
6. Land Cover: The National Land Cover Dataset (NLCD) is complete for the entire U.S. except for Alaska.
7. Structures: Geospatial data on structures in Alaska is virtually nonexistent.
8. Geographic Names: Alaska is one of only four states where GNIS phase II compilation is incomplete.

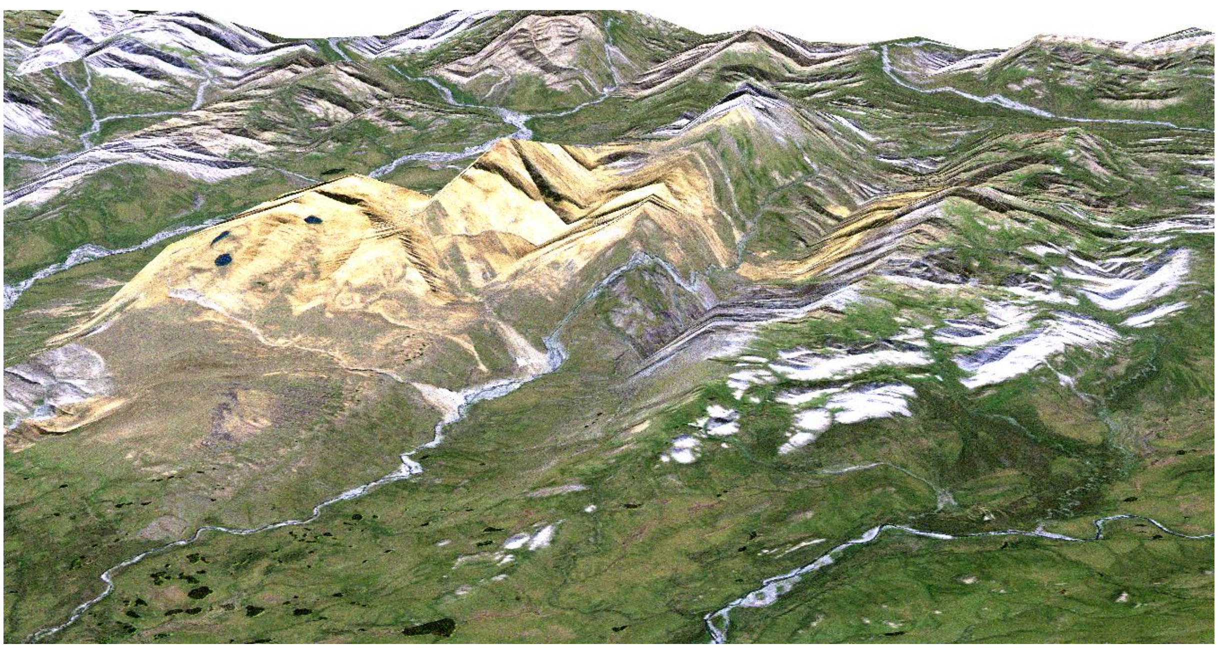

**Figure 1.** Because the Alaska NED is so inaccurate, with some mountains several miles away from their true locations and with the wrong elevations, digital orthophotos of Alaska often show rivers climbing up and over mountains, causing confusion rather than clarity for users and distorting boundary delineations. BLM surveys are routinely based on stream meander lines; however, when streams are not mapped correctly, as shown here, there is no reference of higher accuracy on which to resolve major boundary discrepancies and disputes. The orthoimagery, hydrography, boundaries, and transportation layers of The National Map are all unacceptable in Alaska because of the Alaska NED – the geospatial "log-jam" that prevents progress for most geospatial applications.

## ALASKA DEM WHITEPAPER

In 2008, the Alaska Geographic Data Committee (AGDC) including Alaska Mapped (which represents the SDMI), the Bureau of Land Management (BLM), the Geographic Information Network of Alaska (GINA), and the University of Alaska Fairbanks (UAF) hired Dewberry to prepare a report entitled: "Digital Elevation Model (DEM) Data for the Alaska Statewide Digital Mapping Initiative (SDMI)." This report, released on September 18, 2008, and available at www.alaskamapped.org, is routinely called the Alaska DEM Whitepaper. The whitepaper is the report outcome of the Alaska DEM Workshop held in Anchorage on July 22-23, 2008 and follow-on meetings with project sponsors on July 24, 2008 and August 19-20, 2008. The conclusions and recommendations in the whitepaper reflected consensus of the sponsors as well as all attendees of the Alaska meeting of the National Digital Orthophoto Program (NDOP) and National Digital Elevation Program (NDEP). NDOP/NDEP agencies include USGS, BLM, Federal Emergency Management Agency (FEMA), National Aeronautics and Space Administration (NASA), National Geospatial-Intelligence Agency (NGA), National Oceanic and Atmospheric Administration (NOAA), Natural Resources Conservation Service (NRCS), National States Geographic Information Council (NSGIC), U.S. Army Corps of Engineers (USACE), U.S. Census Bureau (USCB), Farm Bureau Agency (FBA), U.S. Forest Service (USFS), and U.S. Fish & Wildlife Service (USF&WS).

### DEM Requirements

To determine statewide requirements for DEMs, as opposed to project-specific requirements, Dewberry interviewed representatives of six Alaska state agencies and eight federal agencies. Six of these agencies needed high-accuracy DEMs, as typically provided by airborne LiDAR, but all of these requirements were project-specific and not statewide. Seven of these agencies needed mid-accuracy DEMs, as typically provided by airborne IFSAR (Interferometric Synthetic Aperture Radar), and most of these requirements were statewide. Nine of these agencies needed low-accuracy DEMs, as typically provided by radar or optical satellites; these requirements were also statewide. The mid-accuracy requirements were primarily for aviation safety and hydrologic applications statewide, and the low-accuracy requirements were primarily for orthorectification of imagery.

With fewer roads than Vermont, Alaskans rely heavily on aircraft, and pilots routinely need to fly in dark and cloudy conditions under IFR procedures. Many aircraft are equipped with sophisticated navigation equipment that tells the pilot exactly where the aircraft is located, but this can be harmful when the pilot also relies on an inaccurate DEM with mountains in the wrong locations. During 2003-2006, there were 42 aviation accidents in Alaska that the National Transportation Safety Board determined involved Controlled Flight Into Terrain (CFIT), including 40 fatal accidents – each fatality costing ~$2M to investigate. The FAA Flight Plan (strategic plan for 2009 through 2014) and Circle of Safety initiatives are totally focused on aviation safety and CFIT problems in Alaska. As stated above, Alaska is the only state in non-compliance with ICAO standards that require electronic Terrain and Obstacle Database (eTOD) data based on elevation data with vertical accuracies equivalent to 20-foot contours. Also, with the vast river and lake network in Alaska, many state and federal agencies also need elevation data, equivalent to 20-foot contour accuracy, for hydrologic applications.

### Why an IFSAR DEM?

Digital Elevation Model (DEM) is a generic term for a gridded elevation model, either as a bare-earth Digital Terrain Model (DTM) without trees and buildings, or a Digital Surface Model (DSM) of the top reflective surfaces of trees, roofs, etc. IFSAR sees through clouds and produces an Ortho-rectified Radar Image (ORI) with resolution of approximately 1-meter, used to "pan-sharpen" lower resolution images (even partially cloud covered) from all satellite image providers, allowing the production of cloud-free, high-resolution, high-accuracy orthophotos. The DSM is needed to produce the Electronic Terrain and Obstacle Database (eTOD) required to reduce CFIT accidents in Alaska. Furthermore, water features are "loud and clear" on ORI imagery produced from IFSAR.

Figure 2 shows four products that can be produced from IFSAR, including a gridded DEM for the eTOD.

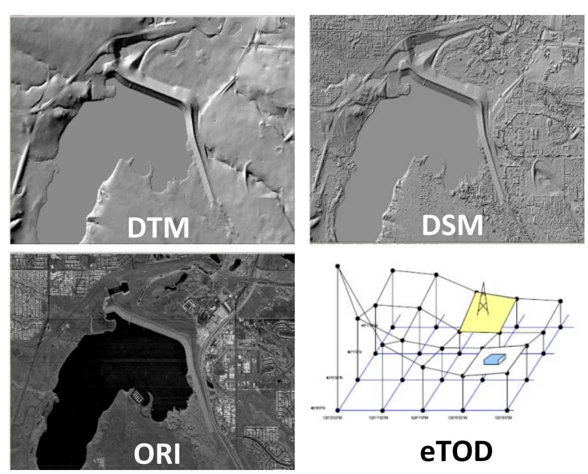


**Figure 2.** Four products from IFSAR.

IFSAR data is collected from an aircraft flying at an altitude of ~35,000' and with 10 Km spacing between flight lines; these are the same flight parameters required for collection of gravity data for NOAA's GRAV-D program so that uncertainties in GPS elevation surveys can be reduced from ±2 meters to ±2 cm statewide. By flying IFSAR and gravity sensors on the same IFSAR aircraft, a significant portion of the costs for NOAA's ($37M) GRAV-D program can be avoided. Similarly, by producing mid-accuracy IFSAR DEMs with 20-foot contour accuracy, NGA can avoid duplicate costs for production of less-accurate DTED2 data (50- to 100-foot contour accuracy) of Alaska that would not satisfy ICAO standards for eTOD data.

Figure 3 shows how the ORI image, which clearly delineates water, can be used to pan-sharpen low-resolution color satellite imagery (to include imagery with partial cloud cover) to produce color, high-resolution orthophotos. The image on the left is an image from the ALOS satellite with 10-meter pixel resolution, and the image on the right shows the same image pan-sharpened with an IFSAR ORI image with 1.25-meter pixel resolution. The color from the satellite image is preserved, and all features are sharpened by the high-resolution ORI and are much clearer and more usable. By georeferencing the satellite image to fit the IFSAR ORI, the image registration process also improves the poor horizontal positional accuracy of the satellite image to fit the higher positional accuracy of the ORI, also assuring that the image being orthorectified is exactly registered to the DTM used for orthorectification.

**Figure 3.** The left image is an ALOS satellite image with 10-meter pixel resolution; the right image shows this same ALOS image "pan-sharpened" with an IFSAR ORI image having 1.25-meter pixel resolution. All features on the right are much clearer, as needed by potential users of orthoimagery in Alaska.

Most other states already have high resolution digital orthophotos and full statewide coverage of mid-accuracy IFSAR DEMs, and most states also have high-accuracy (and much higher cost) photogrammetric and/or LiDAR DEMs. The Alaska AGDC and SDMI have endorsed the Alaska DEM whitepaper's mid-accuracy IFSAR DEM recommendation as both the most appropriate and cost-effective solution for Alaska. This IFSAR DEM is the key to production of the orthoimagery and hydrography layers of The National Map, and the elevation and orthoimagery layers are, in turn, key to production of the boundary, transportation, land cover, and structure layers.

## Partnership Funding Strategies

Deciding on a fair and equitable funding strategy for statewide DEMs is complicated by the fact that the State only owns/manages 24.1% of the land area of Alaska and will pay ~25% of total costs, but the vast majority of land areas are owned and managed by the Federal government, as listed in Table 1.

There are at least 11 Federal agencies that have vested interests in acquisition of the IFSAR DEM of Alaska for execution of their missions, but most agencies lack funds to pay their "share":

1. USGS: Has Circular A-16 responsibility for elevation data and four other layers of The National Map, but it has no significant programmed funding for Alaska mapping.

**Table 1. Alaska Land Ownership**

| | Million acres | Km$^2$ | % of total |
|---|---|---|---|
| **State of Alaska** | 89.8 | 363,408 | 24.1 |
| **BLM** | 82.5 | 333,866 | 22.1 |
| **USFWS** | 78.8 | 318,892 | 21.1 |
| **NPS** | 52.4 | 212,055 | 14.1 |
| **ANCSA** | 39.3 | 159,041 | 10.5 |
| **USFS** | 22.4 | 90,650 | 6.0 |
| **Other private** | 5.9 | 23,876 | 1.6 |
| **DoD** | 1.7 | 6,880 | 0.5 |
| **TOTALS** | **372.8** | **1,508,668** | **100.0** |

2. BLM: Owns 22.1% of the land area for diverse uses.
3. USF&WS: Owns 21.1% of the area for wildlife refuges.
4. NPS: Owns 14.1% of the area for national parks.
5. BIA: Administers lands owned by Alaska Native Corporations (ANCSA) that own 10.5% of the area.
6. USFS: Owns 6.0% of the area for national forests.
7. DOD: Owns 0.5% of the area but needs accurate DEMs statewide for operations and training, etc.; NGA has some programmed funds for mapping of selected areas only.
8. FAA: Requires DEMs with 20-ft contour accuracy for areas surrounding airfields statewide where landings are made under IFR conditions. Although there are officially 148 IFR site terminal control areas in Alaska (see Figure 5), each requiring eTOD with 20-ft contour accuracy, Alaska actually has over a thousand airfields (Figure 4) used to support emergencies under IFR conditions, regardless of official IFR status ─ mostly supporting isolated communities that have neither roads nor ground ambulances to take patients to hospitals and clinics during medical and other emergencies.
9. NOAA: Requires accurate DEMs of coastal areas, plus gravity data for GRAV-D that can efficiently be acquired with airborne IFSAR for all of Alaska.
10. NRCS: Requires an accurate DEM and digital orthophotos for management of the Watershed Boundary Dataset and the National Cooperative Soil Survey, both Circular A-16 responsibilities.
11. DHS: Requires DEMs for emergency response, hazard mitigation, and aviation safety by the U.S. Coast Guard in Alaska.
12. 

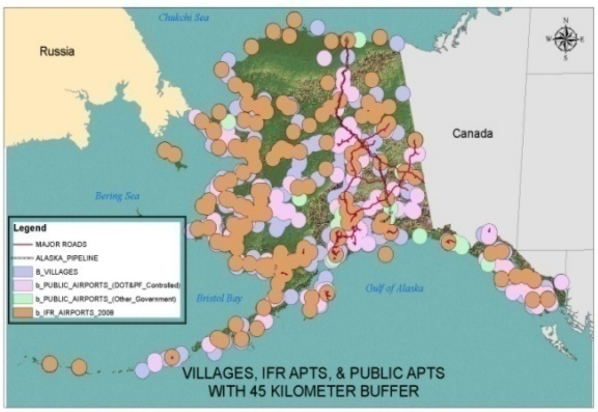


**Figure 4.** Small circles (45-Km radii) surrounding 1,000+ airfields that need IFSAR DEM for eTOD to reduce CFIT accidents. These airfields are routinely used under IFR conditions, even though only 148 of them are officially designated as IFR airfields needing to satisfy ICAO Area 2 requirements.

**Figure 5.** This map shows larger circles that define "terminal airspace" to control transition out of the enroute environment into the terminal environment. This only shows terminal control areas for the official 148 IFR airfields, but still covers the vast majority of the state that needs to satisfy ICAO Area 2 requirements.

The Alaska DEM whitepaper's conclusions and recommendations for urgent actions received the unanimous consent of the NDEP and NDOP, from members of the FGDC Coordinating Committee, and from the department agencies listed above. However, other than NGA, none of the other Federal agencies listed above has funding to pay for any significant share of the required funding for statewide airborne IFSAR.

In order for these and/or other Federal agencies to receive funding for a "fair share" portion of the total funds needed for an Alaska statewide IFSAR mapping project, these agencies would all need to individually seek funding through their normal "stovepipe" committees in the House and Senate. Several agencies anticipate difficulty in getting congressional funding for a task widely seen as USGS' responsibility. Congressional "earmark" funding is a possibility, but the political climate is very poor for earmark funding initiatives at this time.

Because funding for the airborne IFSAR option has not yet been identified, the SDMI is also considering the possibility of using less-expensive satellite SAR technology from Infoterra's TerraSAR-X/TanDEM-X twin satellite constellation, in conjunction with the RapidEye commercial electro-optical five-satellite constellation, in order to produce a statewide DEM and digital orthophotos for Alaska. With this alternative, the SAR's ORI imagery could be used to "pan sharpen" and control the RapidEye imagery in a manner very similar to that shown in Figure 3 above.

## REFERENCES

Maune, David F., Digital Elevation Model (DEM) Data for the Alaska Statewide Digital Mapping Initiative (SDMI), September 18, 2008, www.alaskamapped.org, listed under DEM Workshop Whitepaper.